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The role of public participation, spatial information and GIS in natural resource management of the dry tropical coast, northern Australia

Volume 1

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Thesis Abstract

Public participation is undergoing worldwide recognition as an indispensable component of natural resource planning and management. Nevertheless, effective engagement and communication between resource users and managers is considered the main challenge towards achieving participatory decision-making processes. Spatial information and geographic information systems have been increasingly used as means of engaging and communicating natural resource issues with grassroots groups. The public participation geographical information system has emerged as a promising approach to facilitate visualisation, availability and dissemination of information. It also provides a complementary alternative to traditional participation techniques. However, a meaningful public participation depends on the relevance of the issues involved, the perspectives and interests of participants, the existing cultural, political and organisational contexts, and the level of public participation aimed at being achieved.

The overall purpose of this research was to investigate and document the extent to which public participation processes and geospatial tools have been developed in practice. Three case studies located at the Queensland tropical coast (North Queensland, Australia) were used to illustrate issues, problems and opportunities of integrating public participation, spatial information and related technologies in natural resource management. The tropical coast of the Great Barrier Reef was selected because of the diversity of stakeholder groups that is users of information, resource-use exploiters and information providers. The region also displays a complexity of natural resources decision making processes, an increasing number of public participation initiatives, and current and emergent needs for spatial information and GIS. Three research objectives were addressed to achieve this purpose: (1) analysis of public participation strategies and tools used to communicate with and engage key stakeholder groups in natural resource management; (2) assessment of the extent to which spatial information and GIS technology have been used to furnish access to information and to support participation in decision making processes; (3) development of a conceptual model identifying the key drivers, needs and barriers in terms of participation and use of spatial information and GIS in the management context of the tropical coast.

Data collection involved a combination of qualitative and quantitative techniques including semi-structured interviews, self-completion questionnaires, participant observations, and document analyses. Case studies were selected from both catchment and coastal water systems in the tropical coast of the Great Barrier Reef. The selected case studies provide realistic decision making situations at distinct management scales to investigate the socio-institutional and technical dimensions of the spatial management changes by comprehending how different users understand and make use of spatial information and geographic information tools. Qualitative and quantitative techniques were used to analyse the datasets of the three case studies. Qualitative data composed of document summaries, interviews transcriptions and observation notes were expanded, reviewed and coded. Quantitative data from the surveys were analysed using exploratory and descriptive statistical techniques. Geographic information technology and advanced spatial analysis tools were employed to analyse mapped data.

Regardless of the differences inherent to each case study, findings indicated that many stakeholders are highly motivated and committed to influence decisions on natural resource management. There is also an increasing demand for geographic information technology in land and water management, including real time environmental data to assist with the land and water management process. However, the existing mechanisms, that is the main sources of spatial information and communication tools, the ways geospatial data are developed and acquired, and strategies that people use are not fully supportive of PPGIS initiatives. The public participation processes and the provision of spatial data and use of geographic tools are not fully tailored to the immediate needs of the stakeholders. The current strategies for spatial data acquisition, access and dissemination are mainly driven by government and research institutions. Consequently, most of the immediate public interests do not overlap with the GIS technology and the spatial data provided. The most common factors found in the three case studies investigated were uncertainty about data sources, inappropriateness of the information provided, lack of technical skills and spatial expertise, and inadequate infrastructure.

The research found that despite the limitations found in the three case studies, results of this study provided important and valuable data to support the development of more appropriate ways of interacting, communicating and learning with spatially-referenced data. The conceptual model linked and synthesized the social and technological frames across the case studies providing a coherent framework that integrates the findings of three real natural resource management situations that is catchment, coast and marine systems catchment, coast and marine systems. To enhance support for PPGIS initiatives, users' interests need to be intersected by GIS technology and the spatial data provided. To achieve that, this research recommends that four major strategies need to be addressed: (1) trust between government and resource management agencies with resource users needs to be urgently strengthened; (2) parameters to be measure by geospatial technologies, such as the sensor networks, have to be better linked to a specific management problem, so a more purposive collection and use of data can be designed; (3) investment in collaborative joint initiatives in the use of existing structures and established

community-based networks may possibly strengthen efforts, within and across interested stakeholder partners, facilitating the management, storage, access and acquisition of spatial data and geographic information technology, and (4) effective participation and the meaningful use of GIS and spatial information needs to be adopted as a continuous process, instead of as an end, and as tool to fulfill legal requirements.

The conceptual framework developed and the results achieved in this thesis contribute to general development in the field of geographical research, particularly PPGIS theory and GIScience. Findings of this research provided relevant information on the social, technological and institutional elements that shape and influence public participation and the context-dependent use of spatial information and GIS tools in natural resource management. This thesis touched different management contexts (from water quality of coastal resources to rezoning of marine protected areas and innovative spatial sensor technology), several stakeholder groups (recreational fishers, coastal managers, government agencies, industry, landholders, science providers, and community-based organisations), and a myriad of issues involving public participation and the use of spatial information and GIS. Future research should be directed at investigating the multiple contexts (cultural, social, political and technological) of coupled public participation and geographic information; differential access to geographic information and technology, and public perceptions of space and understanding of the spatial aspects of decision problems.

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Abbreviations and Acronyms

ACTFR	Australian Centre for Tropical Freshwater Research
AIMS	Australian Institute of Marine Science
BDT(NRM)	Burdekin Dry Tropics (Natural Resource Management)
BBIFMAC	Burdekin Bowen Integrated Floodplain Management Advisory Committee
BSES	Bureau of Sugar Experiment Station
BPS	Burdekin Productivity Services
BWQIP	Burdekin Water Quality Improvement Plan
CCI	Coastal Catchments Initiative
CSR	CSR Sugar Australia
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVA	Conservation Volunteers Australia
DEH	Department of Environment and Heritage
DPI & F	Department of Primary Industries and Fisheries
EPA	Environmental Protection Agency
EVs	Environmental Values
CESNNQ	Coastal Environmental Sensor Networks in Northeast Queensland
GA	Geoscience Australia
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
GIS	Geographic Information System(s)
HRIC	Herbert Resource Information Centre
JCU	James Cook University
NCGIA	National Center for Geographic Information and Analysis
NHT	Natural Heritage Trust
MNP	Marine National Park
MPA	Marine Protected Area
NRM	Natural Resource Management
P-GIS	Participatory GIS
PPGIS	Public Participation GIS
RWQIP	Reef Water Quality Protection Plan
WCED	World Commission on Environment and Development
WQBMP	Water Quality Burdekin Management Plan
WQIP(s)	Water Quality Protection Plan(s)
WQO	Water Quality Objectives
WWW	World Wide Web

Publications Associated with this Thesis

Information from this thesis has been published or is currently in preparation to be submitted to peer-reviewed journals.

Publications

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De Freitas, D.M., Kininmonth, S., Woodley, S. (2009), Linking science and management in the adoption of sensor network technology in the Great Barrier Reef coast, Australia. *Computers, Environment and Urban Systems*, 33, 111–121. (Chapter 6).

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De Freitas, D.M., Sutton, S., Moloney, J., Lédée E., (*in prep*). Spatial Displacement and Substitution Choices in Recreational Fishing: Implications of the 2004 Rezoning of the Great Barrier Reef. Target journal *Coastal Management.* (Chapter 5).

De Freitas, D.M., Sutton, S., Tobin, R. (*in prep*). Level of Engagement and perceptions of participation by Recreational Fishers in the Rezoning Process of the Great Barrier Reef. Target journal *Ambio*. (Chapter 5).

Reports

De Freitas, D.M. (2007). Report on the Adoption of Sensor Network by Coastal Managers: An Inshore Water Quality Approach – Workshop 2. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia. 26 July 2007. 31pp.

De Freitas, D.M. (2007). Let’s get together to talk about Public Participation and the use of Mapping Information in the Burdekin Dry Tropics Coast. Workshop Report, 2pp.

De Freitas, D.M. (2006). Report on the Adoption of Sensor Network by Coastal Managers – Workshop 1. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia. 5 December 2006. 44pp.

Conference Presentations

De Freitas, D.M. (2009). Understanding Interfaces of Linked Public Participation and Geographic Information in the Tropical Coast of Queensland. 9^{th} International Symposium on GIS and Computer Cartography for Coastal Zone Management. 30Sept - 02Oct, Itajai (Brazil).

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De Freitas, D.M., Sutton, S. (2008). Spatial Implications of Rezoning of Australia's Great Barrier Reef for Recreation Fishers. 5th World Recreational Fishing Conference November 10-13, Florida (USA).

De Freitas, D.M. (2008). Spatial Implications of Rezoning of the Great Barrier Reef for Recreational Fishers. Spatial Technologies Supporting Regional Queensland Conference. 24-26 October, Townsville (Australia).

De Freitas, D.M. (2008). The use of Spatial Information and GIS in Community Engagement and Management Processes of Natural Resources in the Burdekin Dry Tropics Coast. Coast to Coast 2008, 18-22 August, Darwin (Australia).

De Freitas, D.M., Sutton, S., Moloney, J. (2007). Spatial and Non-Spatial Dimensions of Geographic Information-Based Tools in Supporting Participation in the Great Barrier Reef Coast (Northern Australia). 8th International Symposium on GIS and Computer Mapping for Coastal Zone Management. 8-10 October, Santander (Spain).

Chapter
1

GENERAL INTRODUCTION

Abstract. Public participation is undergoing worldwide recognition as an indispensable component of natural resource planning and management. Nevertheless, effective engagement and communication between resource users and managers is considered the main challenge towards participatory decision-making processes. Spatial information and geographic information systems (GIS) have been increasingly used as means of engaging and communicating about natural resource issues with grassroots groups. However, a meaningful public participation depends on the relevance of the issues involved for the participants, the perspectives and interests of participants, the existing cultural, political and organisational contexts, and level of public participation aimed at being achieved. This chapter sets the context for the development of the dissertation in the field of public participation, spatial information and GIS-related technology. It begins with an overview of the research motivation, followed by details on the need for this research and the identification of the research problem. The general objectives and research questions that underpin this research are next explored. The chapter concludes by presenting the structure of the thesis.

1.1 Research motivation and problem identification

Environmental management problems emerge from particular enviro-geographical locations and have consequences for those areas. Effective stakeholder participation in decision-making is a key element of developing effective planning and management strategies for such problems. Natural resource management agencies are under increasing pressure to consult and include resource's users in the decision-making process (Sutton, 2006). It is expected that engaging stakeholders in the decision making process ensures legitimacy, enhances acceptance, improves transparency, and increases awareness of natural resource management. By engaging in the decision-making process, stakeholders ensure their values, expectations and needs are considered, they increase ownership of management initiatives and enhance understanding of the issue, and they also have the opportunity to minimize negative impacts. Natural resource agencies benefit from the inclusion of diverse stakeholders views, increased public support and confidence, built consensus, reduced and resolved conflicts, increased compliance, and better understanding of the costs and benefits of policy changes.

However, stakeholders cannot participate effectively unless they have a secure grasp of the spatial and non-spatial components that affect environmental changes. Mapping and geographic information technologies are used increasingly to inform stakeholders and collect information from them about the consequences of environmental management decisions (Haklay, 2002; Rambaldi *et al.*, 2005; Rockloff & Lockie, 2004; Schlossberg & Shuford, 2005; Sieber, 2003). For instance, the combination of the interpretative nature of maps with the computerized visualisation techniques has allowed ordinary citizens without any previous knowledge in cartography and geography to produce maps, analyse geographical distributions and spatial phenomena (Goodchild, 1995). For example, the use of spatial scenarios, explicitly those that used modeling, contributed to enhanced perception and increased understanding of water pollution problems caused by intensive pig farming in the Ariranhazinho River microcatchment in Santa Catarina State, Brazil (Bacic *et al.*, 2006). Through an interactive and participatory method, Bacic and co-authors (2006) modeled water pollution scenarios using GIS. In this case, farmers and project extension officers with basic or no previous experience with orthophotos and satellite images could easily locate rivers, streams, villages and other features of interest. The use of spatial information and GIS facilitated the perception of causes, stimulated the collective search for solutions, and strongly influenced opinions in relation to water pollution problems in the microcatchment system. In Australia, the recent re-zoning process of the Great Barrier Reef Marine Park was strongly supported by spatial information in the format of zoning map-questionnaires as the main consultation tool for collecting information from people about their use of the park and their opinions on the locations of proposed new no-take zones. In addition, the aggregation and analysis of numerous map-based submissions and proposed new boundaries was done by GIS tools and spatial analysis techniques throughout the collection, storage, analysis and display of spatial-based information (Lewis *et al.*, 2003). Finally, maps and spatial information establishing the zones and the legal boundaries have also been the major way of communication with key stakeholders of the GBR region.

Nevertheless, such technologies are often used without any consideration of how particular stakeholder groups understand and are able to relate to these technologies. To maximize the effectiveness of stakeholder's participation in decision-making, the use of spatial tools and the delivery of spatial information must be tailored to the unique needs of the stakeholders. Access to and participatory use of spatial information and geospatial technologies, particularly geographic information systems (GIS), has been increasingly used as a means of engaging and communicating about natural resource issues with grassroots groups (Elwood, 2008; Lewis, 2003; Lewis 2006; Oliver, 2004; Swinford 2002; Vajjhala 2006). The importance of combining public participation with geospatial technology has been increasingly recognized in the environmental management process (Corbett and Keller, 2007; Jankowski & Nyerges, 2003; Rockloff & Lockie, 2004; Sieber, 2006).

The so-called Public Participation (or Participatory) GIS (systems/science) has emerged as a promising approach towards the development of interactive tools and methods to support and enhance participation in spatial planning and in the decision making processes (Obermeyer, 1998, Schroeder, 1996). A public participation geographical information system (PPGIS) has emerged as a promising approach to facilitate visualisation, availability, and dissemination of information and provides a complementary alternative to traditional participation techniques (Chamberlin, 2007; Jackson 2001; Obermeyer, 1998). Since then, needs and applications of geospatial data users are growing in terms of diversity, as well as new challenges for data development, dissemination, and administration (Elwood, 2008).

Although spatial analysis techniques and geographical information systems are increasingly used in many decision-making contexts, there is much debate about whether access to this information is truly inclusive. Such technologies are often used by researchers and policy makers without considering how particular stakeholder groups understand and are able to relate to these technologies (Rowe & Frewer, 2004). For instance, Elwood (2008) states that many of the barriers faced by grassroots users in accessing geospatial data are related to insufficient resources, lack of skills, data appropriateness, political and institutional structures, culture and social relationships

The social-institutional aspects of the implementation of geographical information systems have been left behind by the technological dimension, and many information and communication tools have been deployed without considering the local-based context, users' needs and socio-institutional impediments and incentives. It is necessary to understand the mechanisms and dynamics involved in this information delivery before simply assuming that spatial information and GIS improve the decision making process.

Therefore, while the technical aspects of PPGIS are well-known, the socio-cultural and institutional mechanisms, and the potential barriers related to the practical application of geospatial information tools for public participation, require investigation (Rowe and Frewer 2005, Sieber 2006). With a better understanding of the socio-institutional dimensions of applying spatial information and geographical information technology, it can be expected that more accessible, equitably available, and relevant data will be developed (Elwood 2008; Lloyd & Bunch 2003).

The management of natural resources in Australia is characterised by stakeholders with divergent values and objectives over resource use and allocation, often resulting in conflict and competing interests between stakeholders (Harvey & Caton, 2003; Rockloff, 2003; Walker and Johnson, 1996). In the Great Barrier Reef (GBR) coastal region, the engagement with a diversity of stakeholders (e.g. government agencies, industry, communities, landholders, and science providers) to meet the short and longer-term requirements of target setting and to achieve pollutant reductions from land-based sources to improve water quality has been a complex task (Brodie and Mitchell, 2005; Walker and Johnson, 1996).

It has been suggested that much still needs to be understood in PPGIS, particularly on accessibility and usefulness of geospatial information and technology (Elwood, 2008). Together, the increasing role for public participation in environmental decision-making in Australia (e.g. Harvey & Caton, 2003; Lynam *et al.*, 2007) and the growing use of geospatial data as a decision support tool (Jankowski *et al.*, 2006; Rambaldi *et al.*, 2005; Schlossberg & Shuford, 2005) represent the main motivational drivers for conducting this research. Finally, as a quantitative coastal researcher with GIS technical skills, I also have a personal motivation in understanding how public participation, coastal environmental issues and GIS fit together in real life situations beyond the confined context of pure research experiments.

1.2 Significance of the study

International political agendas (e.g. Agenda 21, Principle 10 of Rio Declaration) and legal instruments (e.g. World Commission on Environment and Development - WCED, UN Convention on Access to Information, Public Participation in Decision making and Access to Justice in Environmental Matters-Aarhus Convention) recognize the importance of public participation and the role of modern techniques and methods for more inclusive participation in management and decision making processes. The significance of this research is also supported by the growing number of peer-reviewed publications which examine, analyse and develop new understandings of public participation and geospatial information in natural resources management (e.g. Bacic, *et al*., 2006; Elwood, 2008; McCall & Minang, 2005; Nyerges, *et al.*, 2006; Sieber, 2006; Tripathi & Bhattarya, 2004; Wanga *et al*., 2008).

Whether increased or improved access to information and geospatial technology also increases public participation is still uncertain (Tulloch & Shapiro, 2003), some studies tend to assume a straight relationship between access and application of information, including spatial and GIS, improved participation in decision making processes (e.g. Campbell, 1994; Carver, 2003; Lewis *et al.*, 2003; Pickles, 1995). Others state that PPGIS initiatives are shaped by specific socio-political and cultural contexts (e.g. De Man, 2003; Elwood, 2008; Sahay & Robey, 1996; Sieber, 2006). For instance, from examining the geospatial data needs of small community-based groups in the Chicago region, Elwood (2008) found that, despite improvements in local data integration and development of strategies to increase access to geospatial data and technologies, grassroots data users experienced problems with accessibility, quality and usefulness of local government data resources. In this case, lack of feasibility and appropriateness of the data and technology available did not meet users' needs and limited the use of the spatial information during the planning process.

The present research considers that the analysis of contextual variables can provide valuable data on users' interaction with spatially-referenced data and geographical information technologies. At the GBR management scale, this research provides relevant and timely contribution to the PPGIS field for the following reasons. First, the outcomes of this research have potential implications to inform public policy and government priorities for Queensland's coastal land and waters by contributing to a better understanding of information and communication strategies, capacities and skills that are needed to facilitate design and implementation of public participation processes. Locally, the results of this project can aid in directly supporting key priority areas of the Community Plan for Natural Resource Management in Townsville-Thuringowa (James, 2001). This plan states that actions on community participation in planning need to be supported with appropriate participation mechanisms and also by effective communication and collaboration between groups and individuals involved in the use and management of natural resources (Strategy 6.1).

Secondly, the Reef Water Quality Protection Plan (RWQPP) has listed the Burdekin Basin as a high risk catchment and emphasizes the need for identifying and implementing mechanisms to improve existing participation and collaboration of stakeholders. Therefore, this research provides relevant data to the development of policy targets of the Dry Tropical Coast Regional Coastal Management Plan (draft plan still under preparation) and Water Quality Improvement Plan (WQIP) by identifying the extent to which public participation processes have been developed in practice in the Dry Tropical Coast of Queensland, as well as how geographic information and communication technologies have been used to facilitate access to information and to enhance collaboration. Community and stakeholders' participation and communication strategies represent key components of the Burdekin Dry Tropics WQIP. Traditional public forums and meetings, are proposed by the Burdekin WQIP in addition to innovative techniques such as website, email and workshops and spatial information tools are planned to ensure wide participation in the development and implementation of the WQIP.

Furthermore, it has been reported that although substantial data has been produced, and information and communication tools delivered, there is still the challenge to collect the right data at appropriate spatial and temporal scales in a cost and time effective manner and to deliver it in a format that can be used by management and comprehended by different users (ANZECC, 2000; Kininmonth *et al.*, 2004; State Coastal Plan, 2002). The State Coastal Management Plan - Queensland's Coastal Policy 2002 reports, through the priority areas 2.1 'Coastal use and development' and 2.10 'Research and information' (specifically principles 10A and 10B which address issues on coastal information's collection, availability, and accessibility, and policy 2.10.1 on information management). The need to better address issues of 1) data availability and accessibility, 2) lack of knowledge regarding what information exists or how to gain access to it, and 3) the need to improve community understanding of coastal management issues.

Third, the results of this study will be also an important contribution towards the GBR Zoning Plan, which involved substantial spatial components in the community consultation (e.g. paper maps), development (e.g. use of GIS and spatial analysis), and implementation (e.g. zoning maps) phases of the management process. At the national scale, this research also falls into the strategic priority areas 1 (Integration across the Catchment-Coast-Ocean Continuum) and 2 (Land and Marine-Based Sources of Pollution) of the Framework for a National Cooperative Approach to Integrated Coastal Zone Management (NRMMC, 2006) by understanding stakeholders' roles, access to information, and participative decision making mechanisms in the Great Barrier Reef (GBR) coastal management process.

Finally by collaborating with applied case studies, this study undertakes important strategic research towards a better understanding of the relationship between key stakeholder groups, and how spatially-referenced information and technologies have been and can be better used to strengthen participation in the GBR coast. From a practical perspective, data collected from this research will significantly contribute towards the development of more appropriate ways of interacting (delivering and displaying) with spatially-referenced data, particularly in situations where users have little or no knowledge on how to use or interpret these data. At the conceptual and broader level, it will contribute to PPGIS theory and GIScience research by providing relevant information on sociotechnological elements that shape and influence public participation and the context-dependent use of spatial information and GIS tools in natural resource management.

1.3 General Objectives and Research Questions

The overall purpose of this research is to investigate and document the extent to which public participation processes and geospatial tools have been developed in practice. This research uses three case studies located at the Queensland tropical coast (North Queensland, Australia) to illustrate issues, problems and opportunities of integrating public participation, spatial information and related technologies in natural resource management. The following research objectives are addressed to achieve this purpose:

- Development of a conceptual framework identifying the key frames, concepts and assumptions of different stakeholder groups in terms of participation and use of spatial information and GIS in the management context of the dry tropical coast.
- An analysis of public participation strategies and tools used to communicate with and engage key stakeholder groups in natural resource management;
- Understand how public and participation are framed by different stakeholder groups in the study region; and
- Assessment of the extent to which spatial information and GIS technology have been used to furnish access to information, to communicate and to support participation in decision making processes.

The research questions arising from the above objectives are as follows:

- How is ‘public’ and ‘participation’ manifested in the context of the Queensland tropical coast and among different stakeholder groups for the three case studies?
- Are the ways that spatial information and GIS technology presented to and used by key stakeholder groups to support informed decisions in natural resource management supportive of PPGIS initiatives?
- To what extent does the use of spatial information and GIS strengthen traditional means of communication, participation and cooperation in the management of coastal resources?
- What are the contextual (social, institutional and technical) aspects that influence public participation and shape the use of spatial information and geographical information technology, and to what extent do they support PPGIS initiatives in the context of the case studies?

1.4 Overview of Thesis Structure

To address the overall aim and objectives of this research, this thesis is structured in seven chapters. Due to the diverse nature of its theme and case studies, the thesis passes through many topics from water quality planning of coastal catchments to management changes in coastal marine protected areas and technology implementation in the marine environment. Therefore, an outline of the thesis structure and a brief description of each chapter are provided (Fig. 1.1). In general, the thesis is comprised of three core sections. Section I (‘Overview & Scope’) covers chapters 1 to 3 and provides an overall introduction to the research problem and methodological approach. Section II (‘Practical Context’) describes in detail the context of the three case studies (chapters 4, 5 and 6). Section III (‘Research Findings’) presents general discussion and a synthesis of the data findings of the three case studies. This section finalises with an overall summary of major conclusions and suggested directions for future research (Chapter 7).

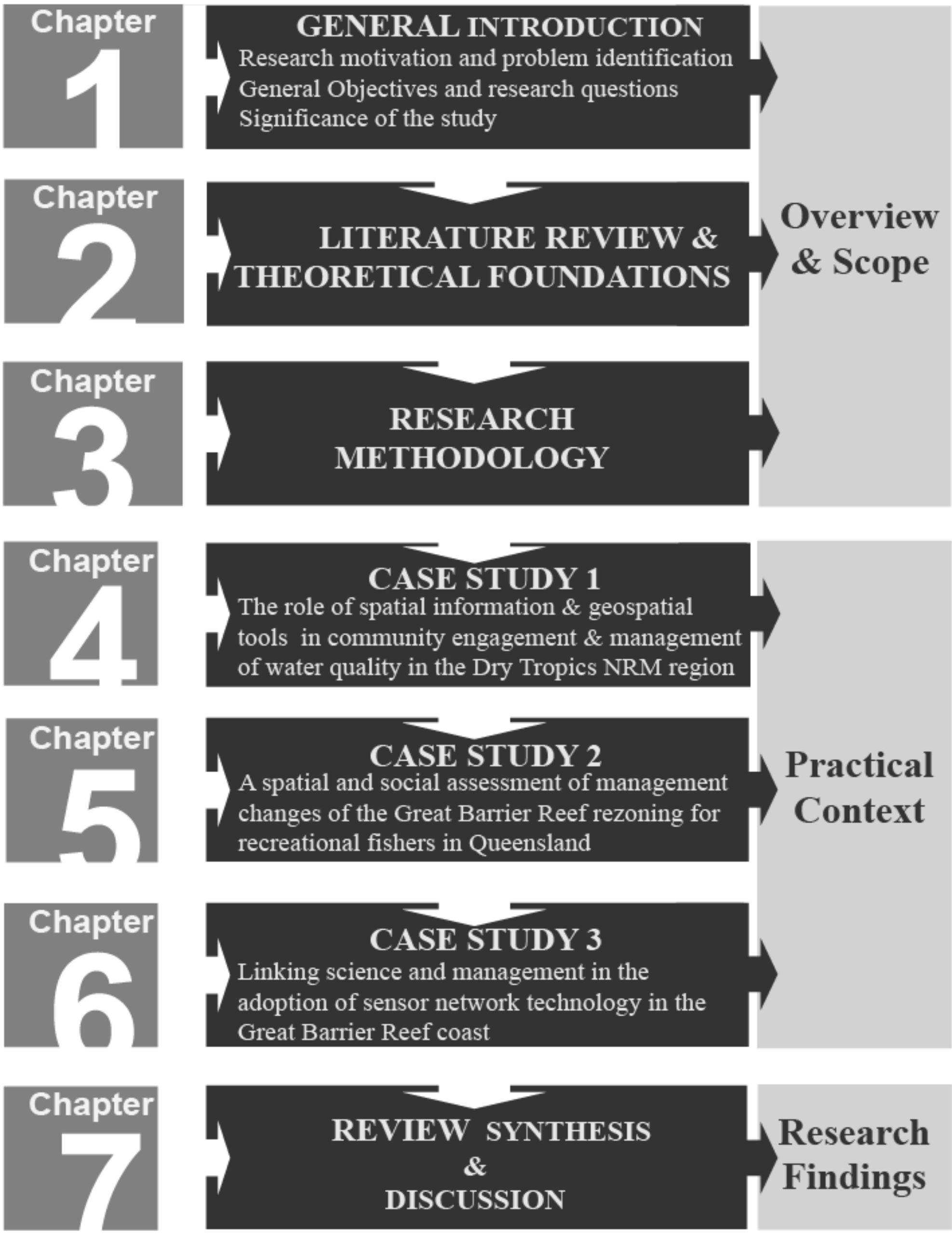

Figure 1.1. Outline thesis structure.

Chapter 1 provides an overview of the rationale of the study, as well as the approach taken to address the problem, the objectives and research questions, and the significance of the research. The literature review on the historic development and current status of public participation and GIS in decision making process is presented in **Chapter 2**. It defines and discusses key terms such as public, participation, GIS, and natural resource management. It also provides a theoretical framework based on Social Constructivist and Sensemaking approaches for exploring the mutual influence of social-contextual and technological conditions that influence people's participation in natural resource management and the use of spatial information and geographical techniques.

Chapter 3 contains the overall research design and methods used to collect the data. The first part outlines the major research design steps and details on sampling strategy and data collection methods. It also presents the ethical issues, as well as the qualitative and quantitative techniques used in the data analysis process. Then it discusses relevant validity and reliability issues, followed by a brief description of the three case studies. Finally, some limitation and bias inherent to the study are addressed.

Chapters 4, 5, and 6 present the practical study contexts used in this research. The first case study on '*The Role of Spatial Information and Geospatial Tools in Community Engagement and Management Processes of Natural Resources Management in Natural Resource Management of the Dry Tropical Coast*' is presented in **Chapter 4**. It draws on the context of catchment water quality management and improvement plans to assess the current level of public participation strategies, as well as the degree to which geo-information technologies has been used to furnish access to information and communication. **Chapter 5** investigates the '*Effects of the Rezoning of the Great Barrier Reef for Recreational Fishers in Queensland*'. This chapter investigates the extent to which management changes in the rezoning of the marine protected areas in the Great Barrier Reef has affected recreational fishing access to the marine resources and the spatial distribution of fishing effort within the Park in the Northern Queensland region. It also addresses the importance of spatial data and geographic information tools in reflecting the effects of management changes in the allocation of recreational fishing effort within the Marine Park. The third case study presented in **Chapter 6** addresses issues of '*Linking Science and Management in the Adoption of Sensor Network Technology in the Great Barrier Reef Coast*'. It identifies the main drivers and barriers to an adaptive deployment of an environmental sensor network in the Great Barrier Reef coast. Specifically, it addresses to what extent the deployment of a sensor network and delivery of real-time data can best suit managers and decision-makers needs by providing timely and useful spatial data.

Chapter 7 integrates the findings of Chapters 4, 5, and 6 to develop a PPGIS conceptual model within the context of the dry tropical coast identifying the key drivers, needs and limitations of different stakeholders. This Chapter seeks to understand and connect the results of the three case studies addressing the needs and challenges for linking public participation and spatial information and technology in the management of coastal resources. The theoretical framework based on practical management situations provides a cohesive and systematic way of understanding the socio-technological and institutional contextual factors that influence people's participation and shape the use of spatial information and GIS-related technology to support better informed decisions. The chapter concludes with a summary of the major research findings and conclusions that arise from this research. It also presents the implications, recommendations, and potential extensions that flow from this research. Conclusions are made with reference to socio-institutional and technical factors that influence the extent to which public participation processes and geospatial tools have been developed in practice for managing natural resources in the Dry Tropics natural resource management (NRM) region.

Chapter 2

LITERATURE REVIEW AND THEORETICAL FOUNDATIONS

From early maps to GIS and WebGIS technologies: the state-of-art of Public Participation GIS in Environmental Planning and Management

Abstract. This chapter begins with a brief overview of the history of maps, cartography and the emergency of geographic information systems (GIS). It is followed by a brief definition of basic concepts, which will be used throughout this chapter and the entire thesis. These definitions are then scrutinized in the light of public participation (or participatory) geographic information systems (PPIGS or PGIS). Subsequently, an overview of major legal aspects of public participation and access to information is presented. Section 2, establishes the main aspects and debates in the recent evolution of coupled public participation and spatial information technologies. The theoretical framework is presented in Section 3 to provide an analytical basis for the investigation of the case studies and development of the thesis. The chapter concludes with a summary of key points that emerged from the literature review.

2.1 Maps, Public Participation GIS and Management

The aim of this review is to provide an outline of how mapping and geographic information tools have been used to support participation in environmental planning and management. In doing so, it presents major historical and current facts in the development of the public participation process and its integration with spatial data and geographic information systems.

Historical Background and Concepts

It should be noted in beginning this section that this brief overview does not attempt to repeat the detailed history and debates on the history of mapping and cartography which is published elsewhere (e.g. Harley, 1989; Pickles, 2003). Rather the intention here is to present a broader context about the importance of ancient maps and cartography, and the recent emergency of GIS and online mapping tools, for planning and management.

The history of maps and the concept of cartography as the science of making maps have its roots in ancient Greece, with the earliest world map of the Greek philosopher Claudius Ptolemaues (Aber, 2004; Biggs 1999). The first print maps in woodcuts and engravings, printed at Bologna in 1477, allowed the reproduction and commercialisation of medieval diagrams and the Ptolemaues' maps for a reading public (Biggs, 1999). An alternative source for map production at the beginning of the sixteenth century was through the support of monarchal nobles. As exchange for material to produce more maps, cartographers provided nobles with cartographic knowledge which became increasingly related to monarchical power (Biggs, 1999).

Before being associated with a symbol of power, maps and cartography were used as expression of art (MacEachren, 2004) and for cosmetic purpose (Harley, 1989). In the Renaissance, maps were displayed as part utensils of the royal ostentation and many artists (in particular Foucault, Deleuze and Guatarri, and Broodthaers) used mapping work to symbolize relationships to the world (Perkins, 2003). Historically, maps have being used as means for visual communication and scientific models of knowledge and cognition (Harley, 1989; MacEachren, 2004).

Cartographic terrain models started to be constructed as a war tool, mainly for military campaigns and frontier defense (Biggs, 1999). According to Biggs (1999), the relation of maps with power and its use for military invading purposes occurred around 1495, when a king of France drew the first terrain map representing the Italian peninsula along with Alpine passes.

Coastline maps of England were also used in the 1530s for the design of defensive artillery fortifications. Maps were also applied by the end of this century as a monarchical instrument for locating nobles and gentry, assessing taxes, establishing the boundaries of administrative units, planning communication routes and managing the royal domain (Biggs, 1999).

The sixteenth to the eighteenth centuries represented the institutionalisation of territorial surveying and map-making by military and scientific agencies and a stronger alliance of cartographic knowledge with monarchical power (Biggs, 1999). However, with the feudal revolution, maps became the basis for restructuring spatial reform by the political authority and they reached a wider reading public spreading throughout Europe in the early nineteenth century.

The twenty century was subsequently characterised by cartography and exploratory mapping environments as model communication systems throughout the world (Crampton, 2001). Since the twentieth century, modern maps became increasingly accurate and precise. However, it was not until the late twentieth century with positioning by satellites mapping by computer (Biggs, 1999), and recently with GIS (Miller, 2006) that spatial information became more available.

The technical transition from the early maps to the concept of GIS represented a major shift in the cartography paradigm in 1970-80s (Aber, 2004). Advances of desktop computers in the 1980s and the networked desktop in the 1990s brought GIS to public- and private sector agencies (Miller, 2006). In the mid-1990s, critical texts began to challenge the truth claims of the increasingly powerful and popular applications of GIS (Perkins, 2003). By the year 2000, spatial information technologies had evolved and had become much more accessible; prices for software and hardware had dropped and spatial information, which until this time had been tightly controlled by governments and elites, became more within the reach of the general public (Chapin *et al.*, 2005).

Community-led GIS initiatives, integrating different voices into mapped worlds, and participatory multi-agency community-based information sharing in GIS became increasingly common (Perkins, 2003). Nevertheless, the promise of GIS to support democratic participation is followed by debates on whether spatial technologies are inclusive or exclusive, empowering or exhausting, democratic or technocratic instruments (Miller 2006). The social context of technology-led GIS initiatives, and the GIS and Society debate reinforced the discussions on the potential of mapping tools as democratising cartographic visualisation (Miller 2006; Perkins, 2003).

Lately, the development of online-based spatial decision support systems (Carver *et al.*, 2001) and the innovative role of GIS/cartography with Google Maps, geowikis, and blogs have re-opened the discourse of democratisation of spatial information and promotion of greater participation (Boulos, 2005;Miller, 2006;Sui, 2008). This issue will be discussed at length in the next sections, particularly in the section about 'Evolution and Debates on Public Participation and GIS.

Defining key concepts

Before going any further, it is necessary to present a brief definition of some of the key concepts that will be used throughout the development of this thesis (Table 2.1). It begins by defining key terms such as 'natural resource management (NRM)', 'map', 'spatial information, 'GIS', 'public', 'participation', and public participation GIS (or participatory GIS)'. However, the following definitions do not represent an exhaustive compilation of all the existing literature in the field. Rather they should be interpreted as a conceptual guide within the context in which they are presented.

Table 2.1. Summary list of key concepts, definitions and sources used in the thesis.

Concept	Definition	Sources (Adapted from)
natural resource management (NRM)	initiatives and practices that focus on the management and protection of values, sustainable use and health of natural resources (e.g. land, water, soil, flora, and fauna)	Cicin-Sain & Knecht, 1998; Lawrence & Deagen, 2001
map	graphic representation of spatial knowledge that locates geographic facts by location	Biggs, 1999; Krygier & Wood, 2005
cartography	the science and practice of constructing maps by employing theoretical and practical knowledge to visually represent geographic information	Harley, 1989; Harley 1990
spatial data / spatial information	data referenced to known geographic location-specific position in relation to the Earth's surface	Leslie *et al.*, 2007; Chamberlin, 2007; Rao & Murthi, 2006
spatial information technology / geospatial technology	set of analytical tools including geographic information systems (GIS), global positioning systems (GPS), and remote sensing image analysis software associated with the collection or manipulation of spatial information	Chamberlin, 2007; Fox *et al*. 2002
GIS	subset of spatial information technologies constituted by a computer-based tool for the capture, storage, manipulation, analysis, modelling, retrieval and graphic presentation of spatially referenced information linked to a database of attribute data	Chamberlin, 2007; Krygier & Wood, 2005; Leslie *et al*., 2007
public	umbrella term used to refer to a broader collection of individuals and groups	Aarhus Convention 1998; Kessler, 2004
stakeholder (s)	subset of the public representing any group/individual who has an interest in, or who is affected (direct or indirectly) by, the implementation of a decision or program	Mitchell, 1997; Schlossberg & Shuford; 2005
participation	process through which stakeholders take part in or become involved in the development of initiatives, decisions and resources that affect their interests and choices in decision process	Hornby, 2004; Nielsen, 2008; World Bank 1996:xi
public participation	the practice of taking part in or becoming involved in an activity throughout different mechanisms such as agenda-setting, decision-making, and policy-forming	Rowe & Frewer 2004; Swinford, *et al*., 2002
public participation GIS (PPGIS)	array of topics and initiatives raised by the intersection of public interests and GIS technology to provide equitable access to spatial data and GIS and to facilitate participation in the decision making process	Elwood, 2008; Ghose 2007; Rambaldi, 2006

Legal Pillars in Public Participation and Access to Information

Since the 1960s, public participation has become an increasingly important aspect of NRM (Lawrence and Deagen, 2001). However, it was not until the early 1970s that legal instruments that promulgated public participation and access to environmental information started to be developed. In 1972, major policy achievements were represented by the UN Conference on the Human Environment (Stockholm Declaration) claimed environmental protection as a key issue, and the first world act on coastal management (CZMA, 1972) adopted by the United States of America.

Significant efforts towards increased public participation and access to information in decision making derived under the umbrella of sustainable development policies. The underlying assumption of both government policies and academic research is that through information sharing, joint learning and understanding, as well as data and information availability, public participation will lead to better-informed decisions, transparent decisions, and improved implementation of policies (Ball, 2002; Haklay, 2003).

Policy instruments started to promote the need of shifting from passive one-way (e.g. informing) towards more interactive multi-way (e.g. active) forms of participation (Fig. 2.1). Principles of equity and decentralized control over decision making emerged to enhance citizen participation in government decision making processes (Irvin & Stansbury, 2004; OECD 2001; Innes & Booher, 2004).

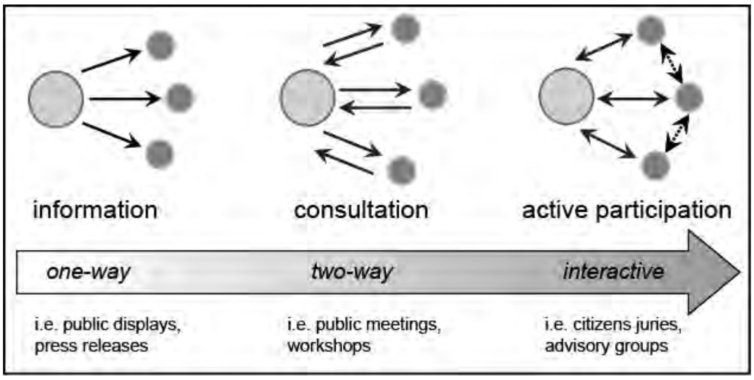

Figure 2.1. Levels of involvement (information to active participation), direction of interactions (one-way to interactive), and mechanisms (e.g. public displays to advisory groups) involved in the relationship between government institutions and citizen groups' participation in policy-making. (Adapted from OECD, 2001).

International political agendas and legal instruments increasingly began to recognise the importance of public participation and the role of modern techniques and methods for more inclusive participation in the decision making process. Improvements of citizen participation in decision making, increased right of public access to information and developments in geo-information technology gained force and became widespread in many government and public institutions in the 1980s (Irvin & Stansbury, 2004). Geo-information technology started to be increasingly recognised as an essential tool for activities such as environmental monitoring and evaluation in decision-making processes (Smith & Craglia, 2003; Vallega, 2005).

From the 1990s, awareness of the important role of public participation increased, as well as the need for wide access to environmental information for sustainable development (Hansen & Properi, 2005). The Principle 10 of the Conference on Environment and Development (Earth Summit, 1992) and Agenda 21 were key milestones towards increased public participation in environmental management decisions. The importance and the need for public engagement in the decision making process is stressed in many chapters of the Agenda, starting with the Preamble of the Chapter 1 which states that:

> *"……… The broadest public participation and the active involvement of the non-governmental organizations and other groups should also be encouraged".*
> (UNCED, 1992)

Additionally, the role of modern techniques such as geographic information and other remote sensing for natural resource management is emphasized in Agenda 21 by Chapters 7, 18, 35, and 40, for example:

> *"…… National and international data and information centres should set up continuous and accurate data-collection systems and make use of geographic information systems, expert systems, models and a variety of other techniques for the assessment and analysis of data. ….." (Chapter 40).*
> (UNCED, 1992)

The UN Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, Aarhus Convention (UNECE, 1998; entered in force in 2001), strengthened public rights and promoted access with respect to participation related to sustainable development (Haklay, 2003; Johnson & Dagg, 2003). Aarhus Convention is composed of three pillars (1) public access to information about the environment, (2) public participation in certain environmentally relevant decisions, and (3) access to courts of law/ tribunals in environmental matters. The second pillar of the Aarhus Convention provides that:

> *"The signatory states should strive to promote effective public participation during the preparation of legally binding rules (e.g. ordinances) that may have a significant impact on the environment" (Art. 8).*
> (UNECE, 1998)

The Convention also recognizes that:

> *"…….each Party shall guarantee the rights of access to information, public participation in decision—making, and access to justice in environmental matters in accordance with the provisions of this Convention" (Article 1).*
>
> *"Improved access to information and public participation in decision-making enhance the quality and the implementation of decisions, contribute to public awareness of environmental issues, give the public opportunity to express its concerns and enable public authorities to take due account of such concerns" (Preamble).*
>
> (UNECE, 1998)

Recently, the World Summit on the Information Society (WSIS 2005), which resulted in the Tunis Commitment and Tunis Agenda for the Information Society, and the WSIS Forum 2009 acknowledge the need for financial mechanisms and public policies for bridging the digital divide, on transfer of technology, on internet governance and related issues in order to enhance the participation of developing countries and all stakeholders.

Overview of Australia's Public Participation Process and Information Access

Public involvement and equity of access to information are predominantly dealt with by the Commonwealth policies (Coastal Policy 1995 and Ocean Policy 1998) and the Australian Freedom of Information Act (1982). The Australian Freedom of Information Act constitutes the main component in the legal context for provision of access to information as a human right and access to information as a means of stimulating information sharing. Although introduced at the federal level in 1982, in Queensland the Act only came into force in 1992. Among other important issues, the Act recognizes that government agencies should provide access to information in the digital environment and online format.

Participation has experienced a regionalisation process and is now mostly integrated in Australian NRM processes (Eversole & Martin, 2005; Jennings & Moore, 2000; Ross *et al.*, 2002). Partnerships between government and communities, and community-based volunteer and stewardship programs are the most common approaches for participation and community engagement in land and coastal management (Clarke 2006; Moore, 2005; Moore & Rockloff, 2006).

Australia's shift from a traditional top-down and centralised approach (1970-80s) toward a more regional approach in the late 1990s was necessary in the face of Australia's environmental movement, large geographic size and comparatively small population (Eversole & Martin, 2005). Consequently, regional institutions became more able to engage communities in regional development processes (Eversole & Martin, 2005; Moore & Rockloff, 2006; Ross *et al.*, 2002).

Community capacity building, Landcare and Coastcare were developed between the 1980s and 2002 encouraging participation in the regional delivery of NRM. The support for such initiatives was mainly through federal (e.g. Commonwealth Government's Natural Heritage Trust - 1990s) and regional (e.g. National Action Plan for Salinity and Water Quality Program-2000s) funding programs and grants schemes (Moore, 2005; Moore & Rockloff, 2006). Landcare and Coastcare both internationally recognized for their roles in increasing awareness, accomplishing on-ground projects to reduce land and water degradation, and improving capacity building of landholders and coastal community groups (Curtis & Lockwood, 2000; Clarke 2006). Despite such achievements, there have been some concerns. Landcare, for instance, has been criticised as a means for government to shift responsibilities to local communities, running with small budgets, insufficient numbers of senior staff, and limited staff with specific knowledge of volunteer management (Curtis & Lockwood, 2000).

In the marine realm, public participation in Australia has been widely recognised for the consultation process of the rezoning of the one of the world's largest marine protected areas (with a total area of 344,400 km^2) (Fernandes *et al.*, 2009). It was a comprehensive and representative multiple-use rezoning which increased the amount of no-take areas (locally known as 'green zones') from less than 5% to 33% (Day, 2002; Fernandes *et al.*, 2005). Public participation in the rezoning was composed of a two-phased community consultation process in which community input was provided mainly through written submissions (Thompson *et al.*, 2004).

Further discussion on specific mechanisms of participation and access to information will be covered by the case studies in chapters 4, 5, and 6.

2.2 Evolution and Debates on Public Participation (and) GIS

"GIS is not a route to the solution but a tool to easy the journey on the route". (Ball 2002:132)

Public Participation (or Participatory) GIS (systems/science) emerged as a variety of approaches and techniques to make GIS and other geographic information tools more accessible and equitably available to all interested parties (Schroeder, 1996; Obermeyer, 1998; Rambaldi *et al*, 2006). Today, the term has been expanded to include the research field that focuses on the public's use of GIS as part of the spatial planning processes (Haklay, 2002; Sieber, 2003). The application of PPGIS in environmental spatial planning has ranged from conventional field-based participatory methods with a modest GIS component to modern Internet-based systems (Steinmann *et al*., 2005).

The participatory use of maps started in the late 1980s, with the adoption of Participatory Rural Appraisal (PRA) sketch mapping tools (Rambaldi, 2005; Rambaldi *et al.*, 2005). In the 1990s, the diffusion of modern spatial information technologies (GIS, GPS, remote sensing softwares, open access to internet) facilitated the integration of geo-spatial information technologies and systems into community-centred initiatives leading to what has come to be known as participatory GIS *(P-GIS)* (Nyerger *et al.*, 2002). Sketch mapping, scale mapping, and transect walking are some examples of participatory techniques intended, according to Chambers (1994), to facilitate and engage local communities to conduct their own analysis and develop their own agendas to promote bottom-up policy development processes.

The current combination of grassroots participatory tools with traditionally top-down GIS techniques emerged as a novel approach for the representation of spatial issues to the general public, providing access to more and better information and enhancing interaction and communication between citizens and decision makers (Steinmann *et al.*, 2005; Tang & Waters, 2005). The Participatory GIS (P-GIS) terminology was first conceived within the scope of the subsequently Project Varenius (Goodchild, 1992) and the National Center for Geographic Information and Analysis (NCGIA) Conference held in Washington in 1993 (Obermeyer, 1998). With the theme 'GIS and Society', the NCGIA's Initiative 19 (I-19) was the main formal initiative related to the use of GIS to support public participation.

In the late 1990s, a series of meetings was held in the United States from 1997 to 1999 to better identify and define the technical and sociocultural implications of geographical information technology (Elwood, 2010). The term Public Participation GIS (PPGIS) was coined at the International Conference on Empowerment, Marginalization and Public Participation GIS, Santa Barbara, California 14-17 October 1998, to cover a specific geographical context (North America), and for a particular purpose: how GIS technology could support public participation for a variety of possible applications. Since then, the overall importance of PPGIS (and PGIS) increased and it is reported by many authors, including Craig *et al* (2002) with the publication of the book 'Community Participation and GIS', and in 2003 with editions of the URISA Journal focusing on GIS access and participation.

There are also several PPGIS and PGIS case studies which demonstrate the success with which the power of maps has been directed to benefit people traditionally lacking a strong political voice. Examples include (but are not limited to): (i) building 3-D spatial modeling for planning and management of protected areas in Philippines (Rambaldi & Callosa, 2000), (ii) involving communities in forest management in Cameroon (McCall & Minang, 2005), (iii) mapping local knowledge for fisheries management in Thailand (Anuchiracheeva *et al.*, 2003) and New Zealand (Hall *et al*., 2009), (iv) enabling local participation in neighbourhood revitalisation in inner-city Chicago (Elwood, 2008),(v) revealing citizens' perception of space about environmental pollution in Taiwan (Sun *et al*., 2009), (vi) supporting rural community involvement in delineating drinking water for protection across the United States (Jankowski, 2009), and (vii) supporting land allocation practice in rural Aboriginal communities in Northern Australia (Monaghan, 2005).

However, despite the growing recognition and application of both terminologies, there is a lack of evidence about whether advances in spatial information and technology will lead to improvements in the decision making process measured by increased public participation, transparency in governance, and better data-driven decision making by community-based organisations (Jackson, 2001; Nyerges *et al*., 2006; Rao & Murthi, 2006; Sieber 2006). The need for more precise and local-based understanding of the public participation process, and the demand for simple participatory structures constitute a considerable impediment to research development in the PPGIS (Tulloch & Shapiro, 2003; Wright *et al.,* 2009). Further investigations are required to assess the implications of integration between GIS, other geo-information, and public participation to facilitate and enhance public participation in environmental decision making processes (Fedra & Feoli, 1998; Carver *et al*., 2001).

There are many challenges and unsettled debates to be addressed in the field of public participation and spatial information technologies and data. In this section, three of those aspects are discussed: (1) the complexity and diversity of current terminologies used in the field, (2) the relationship between public participation and access to information and (3) the sociotechnical discourse.

Conceptualizing PPGIS, PGIS and related terminologies

It has been widely recognized that precise definitions are not simple to determine (Weiner & Harries, 2003). To begin with, the concept of geographic information system itself has been subjected to some discussion.

Traditionally, the definition of GIS had followed a technical path in which GIS is characterized mainly as a system for capturing, storing, checking, manipulating, analysing and displaying geographically referenced information (Chamberlin, 2007; Krygier & Wood, 2005; Leslie *et al.*, 2007. This might be related to the fact that historically the roots of GIS and the development of its technologies have origin in government agency data-gathering and decision-making, and in the design disciplines like the mapping sciences of cartography and surveying, has been limited to the influence of science's needs (Goodchild *et al.*, 1999).

The inclusion of people, producers and institutional arrangements as components of GIS was first introduced by Nyerges (1993). Subsequently, Chrisman (1999: 185) suggested a novel proposal based on the sociocultural and institutional context by stating that GIS could be described as an *"organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures"*. More recently, Elwood (2010) reaffirms the notion of GIS as a multifaceted concept that is viewed not only as hardware, software, data structures, and data, but as an assemblage of technology, methodology, and social practice.

Just as there is not a consensus on the term GIS, a single and concise interpretation of Public Participation (or Participatory) GIS is equally, if not more, challenging (Dunn, 2007). Even though, literally, participation as a noun, or as adjective (participatory), means to take part in or to become involved in something (Hornby, 2004), a diversity of approaches to PPGIS characterisation and implementation have emerged. As a result, the terms 'participation' and 'participatory' have been applied indistinctively, and in most cases inappropriately, to legitimatize top-down approaches (Cinderby, 1999; Rambaldi, 2005) and as synonymous of empowerment (Ghose, 2007; Jankowski 2008; Stoll and Sunm 2005). While a resolution of this debate is far beyond the scope of this thesis, an overview of the distinct views is appropriate to understand the context.

PPGIS researchers (e.g. Ghose 2007; Sieber 2003; Stoll & Sunm, 2005) state that public participation GIS is a field of research that explores the issue of equitable access and use of GIS and spatial data by the general public and interested groups with the aim of facilitating participation and empowerment. P-GIS supporters (e.g. Jankowski 2008; Rambaldi *et al.*, 2006; Voss *et al.*, 2004) describe participatory GIS as a multidisciplinary practice and community-based approach focused towards community empowerment through demand-driven, user-friendly and integrated applications of map-based information and spatial technology. Another perspective claims that public participation should be used as an umbrella term to describe the bottom-up incorporation of the public, from the early stages, into the planning process to improve communication, interaction and joint decision making between different stakeholders (e.g. Johnson & Dagg, 2003; Schlossberg & Shuford, 2005).

Many of these labels are no more than alternative terms for the same or similar methodologies, but there are also some differences in context and approach, mainly between the 'participation' and 'participatory' arenas (Table 2.2.)

Table 2.2. Brief summary of PPGIS and P-GIS approaches*.

	Public Participation GIS (PPGIS)	**Participatory GIS (P-GIS)**
Societal context	North societies	South societies
Origin	evolved as an intersection of participatory planning and geographical information technology and science making use of increasingly sophisticated approaches. PPGIS application occurs within several organisational arrangements	practice emerged as an intersection of participatory progressive development and geographical information technology and science through the integration of low and high tech spatial information management application, and practically essential in rural contexts
Characteristics	interdisciplinary research, community development and environmental stewardship tool grounded in value and ethical frameworks that promote social justice, ecological sustainability, improvement of quality of life, redistributive justice, nurturing of civil society	participatory creation of maps, mainly based on Participatory Rural Appraisal (PRA) methods, usually geared towards community empowerment through demand-driven, user-friendly and integrated applications of geo-information technology
Purpose	utilisation and application of geospatial information and GIS technology by citizens for participation in public processes that affect their lives and so, encompasses data collection, mapping, analysis, and/or decision-making	participatory spatial planning which may make use of maps and other geographical information output, especially GIS

* Based on McCall, 2004; Rambaldi *et al* 2006; Rambaldi *et al.*, 2005

For simplicity, in this thesis the term 'participation' and, consequently, 'public participation (GIS)' will be used in a broad sense to refer to the array of topics and initiatives raised by the need and use of mapping-related information and geospatial tools (including GIS) in supporting communication and facilitating participation in planning and management of natural resources.

Regardless of the lack of consensus, new terminologies continued to develop. Most of the new terms emerged as responses to the debates on the PPGIS and PGIS arenas about whether GIS-related technologies were tools for empowerment or marginalisation (Pickles, 1995; Craig *et al*., 2002), or both at the same time (Harris & Weiner, 1998; Nyerges *et al*., 2006; Sieber, 2006). For some, there was an enormous potential of GIS to provide grassroots groups with equitable access to spatial data and GIS-based analysis and, therefore, enable people to participate more effectively in local governance and policy making. To others, GIS was an elitist tool with technocratic foundations that empower those with knowledge and technical skills while disenfranchising traditionally marginalised citizens. Such views might have their roots in the early history when maps and cartography were instruments in the hands of a minority or a monarch to exert authority and control over the state and its people. It might also be related to critiques of maps as a form of power-knowledge in which the power in mapping practices is context-dependent and expressed by unequal power relations (Crampton 2001; Kitchin & Dodge 2007; Wood 1992).

As a response to those criticisms, other approaches were raised with the aim of facilitating the wider acceptance and adoption of GIS and related spatial information. Advances in computer desktop and networked desktop in 1980-90s, and the rapid development of the Internet, particularly the World Wide Web (WWW) and wireless communication, made possible a broader distribution of spatial information and technology (Albrecht 2006; Miller, 2006; Sarjakoski 1998; Yang *et al*., 2005). Essentially, it was believed that the WebGIS-based environment could remove some of the critical barriers of face-to-face participation such as a confrontational context, and restriction to a geographic location and time (Kingston, 2002; Li *et al*., 2004; Tang & Waters, 2005). The flexibility of '24/7' (24 hours a day and 7 days per week) access, an anonymous participation, and a non-confrontational environment represented considerable advances (Kingston, 2002).

Consequently, new streams of terminologies emerged from the integration between public participation, GIS and the internet (Fig. 2.2).

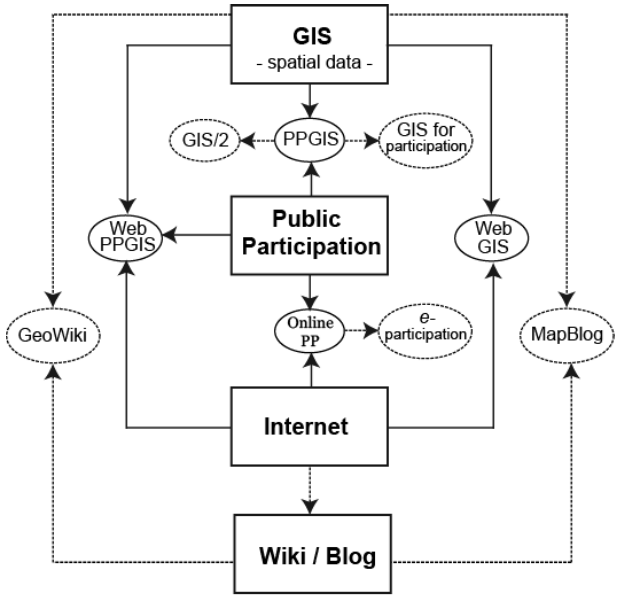

Figure 2.2. GIS, public participation, Internet and its interactions (◯) and ramifications (◌). (Adapted from Tang & Waters, 2005).

GIS/2 (GIS-2), for instance, was initially conceptualized at NCGIA's Initiative 19 as an attempt to define functional criteria for the second generation of geographic information systems (Sarjakoski, 1998). It characterises a set of processes and instruments in which the technology itself would be one of the components but the main focus to communicate representations such as creation and evaluation of spatial data (Tang & Waters, 2005; Sarjakoski 1998), matrices, and models (Miller, 2006).

GIS for Participation (GIS-P) is another term employed by some scholars and practitioners to describe the use of new technologies to captures local stakeholders' knowledge in a spatial format suitable for incorporation into a digital spatial database (Cinderby, 1999). It is also a type of PPGIS in which GIS is used as a tool to facilitate participation in decision making. However, the participants themselves are not directly responsible for data infrastructure and analysis (Cinderby & Forrester, 2005).

WebGIS, also known as web-based GIS, Internet GIS, online (e-) GIS, and online PP, represents the integration of traditional GIS using the Internet as a basic information infrastructure for spatial data dissemination and simple analysis (Tang & Waters, 2005). While GIS has existed for decades, the development of WebGIS is a recent phenomenon that has greatly changed the way in which data are produced and delivered (Kingston *et al.*, 2000). Increasingly, people are using WebGIS interface in map query activities (e.g. Google maps, Mapquest, and Terraserver), government projects (e.g. Virtual Slaithwaite in England - Kingston *et al.*, 2000; and IntelCities in Europe – Kingston *et al.*, 2007), and research-based initiatives (e.g. e-Atlas Interactive

Mapping Service of the Great Barrier Reef). In addition, Google Earth has provided to internet users access to geographic information in a 3-dimensional format (Boulos, 2005).

GeoWikis and *MapBlogs* are the most recent and revolutionary promise towards a truly interactive and collaborative mechanism in the web world. A *Geowiki* incorporates the same principles of a wiki in which content can be edited by anyone who has access to it (Boulos, 2005). Similarly, by incorporating ideas of blog content, a *MapBlog* would contain geo-referenced entries in reverse chronological order about a specific topic. The 'wikification of GIS', as it has been called, it is still in early stages but it is opening a whole new range of possibilities for exchange of geographic information and interactive map applications in a much faster and interactive way (Boulos, 2005; Sui, 2008).

The complexity and diversity in approaches, views and terminologies is not just contributing the advancement of GIScience research, but it also expanding further theoretical thinking by proposing the use of terms such as 'neogeography' to represent innovations and new applications of online geospatial technologies and sourced spatial data outside the realm of traditional GIS (Elwood, 2009; Haklay *et al*., 2008; Sui, 2008).

Overall, under different labels and diverse contexts, there is an underlined and implicit trend that associates more and better access to information which results in improved or higher levels of participation. The next section will explore in more detail the issue of public participation and access to information.

Public Participation and Information Access: is it a linear relation?

As other aspects in the recent history of the PPGIS field, there is an ongoing discussion on whether access to information and ownership leads to enhanced public participation in the environmental planning process (Smith & Craglia, 2003). Spatial planning and public participation were only recently considered as an integrated issue (Schlossberg & Shuford, 2005). As such, PPGIS supports that spatial visualisation and analysis capacities inherent in GIS represent an opportunity for enhanced citizen involvement in public policy and planning issues (Al-Kodmany, 2001). Overall, discussions about PPGIS are often shaped by the assumption that access is a condition for participation, whereas restricted or no access has prevented participation (Tulloch & Shapiro, 2003).

Frequently, debates about Web-based GIS, for instance, are shaped by the assumption that online tools not only facilitate access to information and contribute to public awareness, but they also increase the level of public participation in planning (Carver, 2003; Sadagopan, 2000). Conversely, other scholars state that, while access to (geographic or spatial) information is an important step towards participation, there is not a linear relationship between them (De Man, 2003; Laituri, 1998; Tulloch & Shapiro, 2003). In fact, more opportunities in information technology and participation might allow the public to influence the planning outcomes, but it does not automatically imply better decisions (Blaschke, 2004).

In Australia, for instance, access to GIS applications and Internet technology has not been sufficient in promoting relevant public participation (Yigitcanlar *et al*., 2003). Major constraints include lack of readiness to accept information and communication technologies, absence of matching the available technology with user needs and lack of appropriate skills to access the technology.

Using hypothetical examples, (Tulloch & Shapiro, 2003) exemplify the extremes of four possible types (scenarios) of integration between information access (from no or low to high) and levels of participation (from no or low to high). The study shows that no or low levels of access and participation (Type I), and high levels of access and participation (Type IV), reflect the conventional assumption about a positive relationship between access to information and participation in decision making. Type I is more likely to occur, for instance, in situations with limited interest from the government to allowing the public to have any role in decision making. Type IV would represent an individual or organisation which acts independently to acquire spatial data to support its influence in an environmental policy. Intermediary categories are represented by Types II (high levels of access, but no/low levels of participation) and III (no/low levels of access, but high levels of participation). A situation characterized by complaints of pre-determined decisions and inadequacy (e.g. too complex or erroneous) of the data available would reflect a Type II. A Type III category might be represented by a community association acting on its own behalf in data to produce maps from existing data sources to support their participation in the decision-making process. With this typology, Tulloch & Shapiro (2003) summarised different possibilities of information access and participation contrasting the basic assumption of linearity between access and participation.

This controversy is extended to uncertainties inherent to the concept of access itself. For Smith & Craglia (2003), for instance, access needs to be defined in a more comprehensive context encompassing technical (e.g. access to digital infrastructure), social (e.g. individuals' skills), and political (e.g. equality of rights) aspects. According to them, access to information, including digital access, is still based on principles of empowerment since the main purpose is not only to access and understand the information, but also to make effective use of it by influencing power and affecting outcomes.

In particular, such discussions and uncertainties make questionable one of the most recognised models of public participation in the PPGIS international literature, the ladder of public participation. First described by Arnstein in 1969 and subsequently reviewed by diverse scholars (e.g. Carver, 2003; Kingston, 2002; Smith 2001; Tang & Waters, 2005; Wiedemann & Femers 1993), the ladder approach (including the *e*-participation version) presents different levels of participation (from the public right to know to public participation in final decision) directly increasing with the level of communication (ranging from one-way to two-way). In most cases, the ladder approach proposes that a growing use of spatial technologies such as GIS would directly imply in an increased level of public involvement in the decision process. Thus, if it is not possible, at least at this stage, to affirm if there is a direct and/or linear relation between access to information and public participation, the ladder's framework needs to be reviewed. For instance, the *e*-participation ladder presents information and communication technologies as breaking down key barriers to participation (Carver, 2003). The component 'increasing participation' in the *e*-participation ladder presented on the left side of the ladder, should be replaced for 'increasing accessibility or connectivity'. Further discussion on the existing models of public participation and PPGIS is explored by the next section.

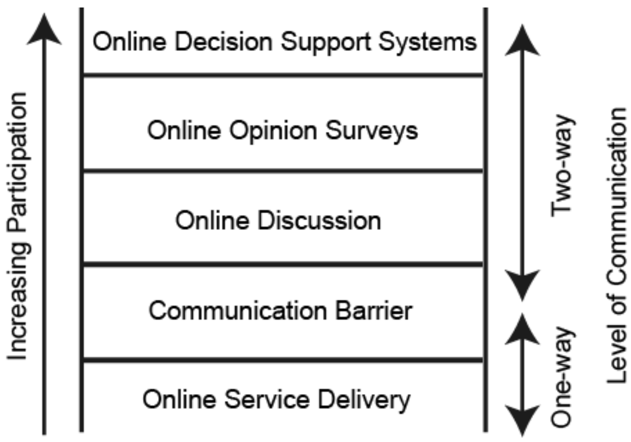

Figure 2.3. The *e*-participation ladder. (Source: Carver 2003: 63).

In conclusion, the relationship between public participation and access to information is a complex question and there is a great need for better understanding the linkages between both (Ghose & Elwood, 2003; Smith & Craglia, 2003; Tulloch & Shapiro, 2003). Research based on grounded socio-spatial contexts of realistic decision-making situations can provide valuable information to contribute to the debates on public participation and access and use of geospatial tools and spatial information.

The Sociotechnical Discourse

There are a myriad of social and technical challenges involved in the development of PPGIS and related fields. While recognising that it is not possible to cover all issues in one chapter and that some of these issues might be more appropriately considered elsewhere, the following are some of the sociotechnical issues relevant within the context of this thesis.

The role of GIS and related spatial information in a societal context, and particularly public participation, has become a major research topic in the emergent Geographical Information Science-GIScience (Goodchild, 1992; Nyerger *et al*., 2002; Ghose & Elwood, 2003) and, more recently, in Neogeography (Elwood, 2009; Haklay *et al*., 2008; Sui, 2008) and Collaborative GIS (Balram *et al*., 2009; Balram and Dragićević, 2006). Because the integration of public participation with GIS and spatial information is a relatively recent phenomenon, adoption is occurring without full evaluation of its suitability for societies and organisations, or the costs and benefits of its use (Ventura, 1995).

It has been argued that data access and PPGIS initiatives are mainly guided by the social context in which they are included, and so, both are greatly influenced by culture and institutional features (De Man, 2003; Ghose & Elwood, 2003). De Man (2003) argues that both socio-cultural (by shaping people's values, expectations and decisions) and distinct institutional arrangements (by governing power and control over political decisions) determine information needs, access and use of geographic information, and, consequently are reflected of people's values. Therefore, if the social objectives of spatial technologies are to be achieved, it is critical to understand the social context and its interaction with different levels of adoption, development, and use (Elwood 2009; McMaster & Usery, 2004; Sahay & Robey, 1996).

In addressing the societal implications of geospatial technological development and its consequences, some scholars call attention to issues emerging from the unequal access to information and the 'cybernetisation' of participation tools (Elwood, 2009; Paolillo *et al.*, 2005; Stoll & Sunm 2005). Paolillo *et al*., (2005: 44) and claim that the *"unequal distribution of access to digital information sources and services"* is dividing society between those who have access and are able to read the internet language, and others who do not. This digital divide raises many questions, such as whether linguistic differences will constitute a barrier to information access, or whether current policies should better address equality access problems as a way to break down or to minimise traditional social barriers (Paolillo *et al*., 2005). In addtion, Elwood (2009: 1) suggests that the "*changes in content and character of digital spatial data that are emerging from the geospatial web (Geoweb)*" are associated with shifts in the processes and power relations of spatial data creation and use, as well as shifts in social relations.

For example, Rao & Murthi (2006) recently called into question whether geographic information and related technologies can still be considered 'public (societal) goods' (Rao & Murthi, 2006). In this study, they defined public good as one where "*there is non-rival consumption and that the cost does not depend on the number of users*" (p. 265). However, increasingly, private companies are dominating the acquisition and processing of spatial data and creating market value information which has raised many concerns (Perkins & Dodge, 2009). Public claims for information availability and political transparency on data gathering and dissemination of information are conflicting with the restrictive commercial interests of private companies (Rao & Murthi, 2006).

In addition, the progressive shift from coarse resolution (e.g.~ 30 metres) and broad information towards timely-high resolution (e.g. <1 metre) imagery has enhanced concerns on issues of national security, sovereignty, and intrusiveness (Perkins & Dodge, 2009; Rao & Murthi, 2006). The possibility that the location of sensitive places (e.g. infrastructure networks, water supply systems, nuclear power stations), and military installations, for instance, are at the fingertips of everyone, is changing values and politics worldwide (Perkins & Dodge, 2009).

By contrast, other scholars support the view that recent tools such as Google Maps and other open-source spatial softwares are overcoming societal barriers such as unequal access to information and lack of technical skills (Boulos 2005; Miller 2006; Sui 2008). Both Boulos (2005) and Miller (2006), for instance, emphasise that the Katrina Information Map initiative, which was built using Google Maps by people affected by Hurricane Katrina, allowed users fast access to information about the status of specific locations affected by the storm and its effects. The interactive map also allowed users to easily contribute to the map by adding or appending their information to it (Boulos, 2005). In this case, people affected by Hurricane Katrina inserted updated and critical information about the status of areas impacted by the storm, which in most cases were not even mapped yet.

To conclude, as any other recent research in development, public participation (participatory) GIS is still an unsettled and transformable field. As such, there are foundation questions of usefulness, access, technology diffusion, and outcome measurement to be addressed (Wright *et al*., 2009). Most of the social and technological debates are related to issues of empowerment and communication embedded within multiple scales (from national to a single community) and distinct frames (from sovereignty to natural disaster management) in which social construction and relationships shape the role and need for spatial information and related technologies.

2.3 Scoping Frameworks in Public Participation and Geographic Information Technology

Since the emergence of public participation GIS, a number of different explanatory models have been applied to public participation in environmental decision-making processes. This section does not aim to provide a comprehensive review of all the existing approaches in the field, which are numerous and continuously increasing. Rather, it provides an overview of some of the most relevant frameworks within the scope of this thesis grouped into five major typologies: ladder (Arnstein; 1969); wheel (Davidson, 1998); spectrum (IAP2, 2006), conceptual map (De Man & Van den Toorn, 2002; Nyerges, 2002), and the collaborative GIS cube (Balram *et al*., 2009; Dragićević & Balram, 2006).

The most recognized attempt to describe public participation as a multi-level process is the *Ladder of Citizen Participation'* proposed by Arnstein (1969). The citizen participation ladder frames public participation in a continuum of power orientation that extends across eight rungs of the ladder, from passive or non-participation (e.g. therapy, manipulation) to degrees of tokenism (e.g. information, consultation, placation) and power-sharing active engagement at the top (e.g. partnership, delegated power, and citizen control). Arnstein noticed that despite the existence of a range of avenues for public participation, most efforts did not allow individuals real influence on the outcome of the decisions taken. The ladder provided the theoretical landmark by claiming the redistribution of power from those in which government dominates decision-making to ones in which its power is shared equally with the public or communities (Buchy *et al*., 2000; Ross *et al*., 2002).

Arnstein's ladder metaphor has been rethought in a variety of PPGIS contexts (Conner, 1988; Dorcey *et al*. 1994; Kingston, 2002; Sarjakoski, 1998; Swinford *et al.*, 2002; Treby & Clark, 2004; Tang & Waters, 2005; Tulloch & Shapiro; 2003; Weidemann & Femers 1993). Most studies explored the nature of the relationship between public participation, participatory tools and the influence in the decision making process. For instance, Conner (1988) characterised public participation through a range of participation techniques to be used for preventing and disputing resolutions, from education of the general public to preventive activities by decision making leaders. Dorcey *et al*. (1994) offered a different spectrum for effective participation recognising that the nature of public participation can change over time from being informed to ongoing involvement within a single planning process. Weidemann & Femers (1993) adjusted Arnstein's participation ladder to reflect a common understanding of access to information as a form of participation. The '*Ladder of Public Access'* was used to describe the degrees to which data users might use or acquire public data from a variety of public and private sources. According to this ladder, participation increases with access to information ranging from public right to know, informing the public, public right to object, public participation to defining interests, public participation in assessing risks and recommending solutions to public participation in final decisions. The ladder was subsequently expanded focusing on how information and communication technologies, particularly online GIS, could better encourage and increase public participation (Carver, 2003; Kingston, 2002; Smyth, 2001). In the *'e-Participation Ladder',* participation increases from one-way (e.g. online delivery of information) to two-way communication (e.g. online support decision systems) according to the level of interactivity between server and users increases from one-way (e.g. online delivery of information) to two-way communication (e.g. online support decision systems).

The *'Spectrum of Public Participation',* developed by the International Association for Public Participation (IAP2) in 2000 , demonstrates five possible types of stakeholder engagement .The level of public impact increases through the spectrum from left to right – inform through to empower. In an informative and more passive type of participation, the public is only provided with information (e.g. fact sheets, public displays) about a particular project and no input occurs. At this level, the role of the stakeholder is totally passive and the management agency has complete control over how, what and when stakeholders are informed. At an intermediate level of participation, stakeholders are consulted, mainly via public comment, and their views and suggestions are explored by the management body. Stakeholders might also be involved (e.g. participate at workshops) or collaborate (e.g. integrate citizen advisory committees) in the decision making process and information is shared in a two-way interaction between stakeholders and management agencies. Finally, at the end of the spectrum, empowerment, the final decision lies with the public and therefore an increased level of public impact, represented for instance by citizen juries.

The ‘*Wheel model’* of participation proposed by Davidson (1998) provided a more flexible and non-hierarchical approach emphasising the legitimacy of different degrees of engagement as circular rather than a linear form (Reed, 2008). While maintaining the main categories (inform, consult, participate and empower) suggested by Arnstein (1969), the circular model proposed several stages (subcategories) distributed around the wheel to represent different levels of engagement that are likely to be appropriate in different contexts (Reed, 2008). For instance, the ‘inform’ category was represented as minimal communication, limited information and high-quality information, while ‘empower’ was represented in terms of delegated control, independent control, entrusted control.

A more structured framework integrating the social, cultural and institutional aspects of participation with the use of geographic information technology was considered by the *conceptual map approaches*. Instead of categories and levels, conceptual maps provided a more systematic framework integrating different aspects of participation and use of spatial technologies. Nyerges *et al.* (2002), for example, developed a framework, the Enhanced Adaptive Structuration Theory (EAST), to understand the social-behavioural implications of advanced spatial information technologies for group decision making in an organisational context. Their framework, an extension of adaptive structuration theory, derives from a comprehensive synthesis of fifteen theoretical frameworks and assessment of research dealing with GISystems use, collaboration, group decision making and information technology more generally (Jankowski & Nyerges, 2003). As an organizational structure framework, EAST suggests that people structure situations; in turn, situations structure people’s interaction (Jankowski & Nyerges, 2003). Neither technological nor social character of an organization predominates in change. Instead, they work together to structure and, hence, reconstruct each other, the fundamental idea underlying adaptive structuration (Nyerges *et al.,* 2002; Jankowski & Nyerges, 2003).

The EAST framework consists of a set of eight constructs (the elements of the theory, e.g. social institutional influence, participatory GIS influence, group processes) clustering twenty five aspects (e.g. rules and norms of participation, channels of communication) of groups, information technology use, and/or decision making for complex problem solving (Nyerges *et al.,*2002). It is also composed of a set of seven premises (e.g. given particular GIS technology and other structures, if specific appropriation occurs and decision processes fit the task, then desired outcomes result) that describe the relations among the eight constructs. Constructs reflect the structure, while aspects address the content of participatory decision making and are tied through premises which in turn represent fundamental statements about the nature of the process (Jankowski & Nyerges, 2003). The framework links premises with research questions and testable hypotheses to understand the social-behavioural implications of group use of GIS because groups are fundamental units underlying intra-organizational, organization-wide, and inter-organizational activity in society (Nyerges *et al.*, 2002).

Nyerges' framework acknowledges that successful implementation of participatory decision-making requires not only the need to understand the values and expectations of those involved, but also the availability of data about the problem, and the socio-political context that influences that decision problem context, and the use of geographic information technology. In summary, the framework provides constructs and premises that help to interpret how people make use of certain types of information in a given problem context and explains the elements involved in structuring human–computer-human interaction.

For example, Drew (2003) used the EAST framework to investigate the use of geographic information and Internet-mapping based technology as decision support systems in a management process related to managing nuclear waste and cleaning up in the Columbia River located in the southeastern region of Washington State. Drew's main construct was framed by the need for improved transparency in a complex environmental decision making process in which people wanted to know how to participate, understanding the technical, environmental and institutional issues involved, and how to get the information necessary for a decision. The complexity of federal and state regulations, fragmented information, and disconnected decisions constitute the most important aspects in such a context. As a way to enhance transparency and openness in the process, the basic premise focused on the development of a decision mapping system using GIS and the Internet as a useful tool to promote two-way information exchange among the decision-makers, active stockholders, and the general public about the cleanup process. While GIS was used to integrate information and facilitate participants' synthesis of spatial-based knowledge, the provision of data through the Internet fostered physical accessibility to the information provided. A participatory approach was used to incorporate the values and views of several stakeholder groups at National, regional, and local level and to evaluate the tool. Using the EAST framework, Drew identified and explained the key social-behavioural and technological elements involved in a group decision making context. Furthermore, the research was able as successful in proving its premise and testing the hypotheses that decision mapping systems allow a better understanding, and facilitate people's participation the decision process of cleanup activities and nuclear waste management. A major outcome of the process was the designation of the decision support system as a national repository for nuclear waste receiving high priority as a local, regional, and national issue.

Following a similar approach, De Man & Van den Toorn (2002) proposed a conceptual model to explore the interplay between culture and the adoption and effective use of geographic information technologies. In this framework, GIS-technology adoption occurs within organisations rather than through individuals, and organisations perform functions within and towards their societal environment. However, the distinction between societal and organisational cultures is pointed out as critical to understand the desirability of the recipient social conditions for the use of GIS and the feasibility of the development and effective application of GIS technology.

The *'Collaborative GIS Cube'* framework, first proposed by Dragićević & Balram (2006) and recently updated by Balram *et al.*, (2009), attempted to support the complex issue of societal problems and spatial technological challenges by structuring participation in group spatial decision processes. Their hypothetical framework categorizes four possible trends in planning and decision making by integrating levels of participation (private, public), map usage (none, high) and technology (non-digital, local area network, internet/wireless) into three mutually perpendicular axes of a cube (Fig. 2.4).

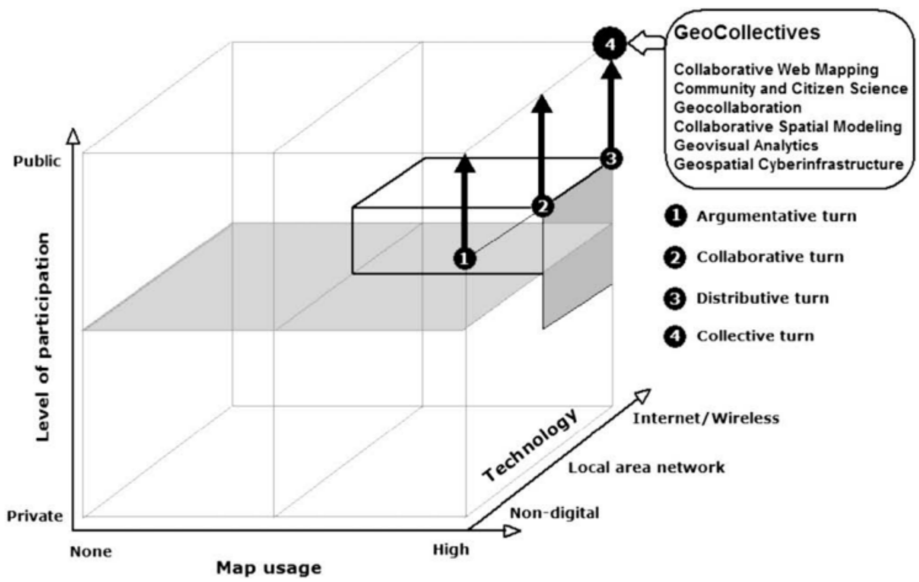

Figure 2.4. Collaborative GIS cube. (Source: Balram *et al*., 2009: 1964. Permission to reuse in this thesis was granted by Elsevier on 06th June 2009).

For instance, in the first scenario, the argumentative turn, participation occurs at a small group level with high usage of traditional maps and graphics and technology is mostly non-digital. Turn is the term used by Dragićević and Balram (2006) to characterise groupings or multiple regions of interactions that share some common motivations and goals. At the collaborative turn, participation is represented by deliberation and consensus in group settings, maps are highly used to explore and construct scenarios, and technology is mostly digital. The need to expand participation towards public levels and more diverse range gradually leads to a distributive turn to planning, whereas a collective turn emerges where a large group of participants become fused with the technology as a single decision-making system (Dragićević & Balram, 2006).

Overall, a substantial progress has been made towards more integrated and structured ways to understand the complexities of involving public participation and the use of spatial information and geographic technology as means of engaging and communicating in decision making processes. Nevertheless, recent studies have shown that, in general, the social issues associated with new technologies are still not fully understood (Russell *et al.*, 2010). The present research aims to contribute to the filling of this gap by proposing a theoretical framework that considers different aspects of stakeholders' needs, socio-institutional and technical factors influencing public participation, and shaping the use of mapping information and geographical information. The framework advances on previous work developed by Sahay and Robey (1996) and De Man and Van den Toor (2002) by presenting a coherent approach that synthesizes key elements raised by the intersection of public participation interests, GIS technology and spatial information within practical decision making situations.

The model presented in the next section makes no claims to constitute a complete and inclusive attempt to cover of all possible aspects involved in the research topic. Rather, the framework represents a structured way to outline and understand some of the core components that emerged from the investigation of the research findings. The analytical framework is revisited and expanded in Chapter 7 to illustrate its usefulness in light of findings of the three case studies presented in Chapters 4, 5 and 6.

2.4 Theoretical Framework: Scoping and Understanding

"Technology is never purely technological: it is also social. The social is never purely social: it is also technological"(Bijker and Law, 1992: 305)

Spatial information and GIS have been increasingly used as important decision support tools in environmental decision making processes (Swinford, 2002). Despite increasing incorporation in to the management of natural resources, spatial information and geographical techniques have been applied in decision making processes without considering the local-based context: people's willingness to participate, user's needs, socio-cultural and institutional implications, potentialities and constraints (De Man, 2003; Rowe & Frewer, 2005; Russell *et al*., 2010). For instance, different needs in terms of spatial data accuracy and precision expressed by multiple stakeholders may lead to the development of incompatible or duplicated GIS datasets by management agencies (Sahay & Robey, 1996).

The use of non-local spatial data and complex software in capacity-building workshops and training sections can affect people's willingness to participate because they are not used to it. In other cases, changes in institutional circumstances such as the appointment of a new manager may provide the necessary resources to influence the adoption of GIS technology (Campbell, 1994). Therefore, while spatial considerations may develop into improved stakeholder understanding and satisfaction, the mechanisms and dynamics for the incorporation of spatial considerations into the participatory process needs to be addressed (Dunn, 2007; Jankowski & Nyegers, 2001).

An advanced understanding of stakeholders' needs and the socio-institutional and technical aspects influencing public participation and shaping the use of mapping information and geographical information technology can support effective communication and facilitate involvement in decision-making. The so called 'social shaping of technology' (Bijker & Law, 1992; Williams & Edge, 1996) or 'social construction of technology' (Klein, 2002; Elmes *et al*., 2005) has its roots on the pioneer studies of Pinch and Bijker (1984). It underlines the importance of the socio-cultural and institutional factors in the adoption and use of new technologies such as GIS within social groups (e.g. organisations) and societies (De Man & Van den Toorn, 2002; Leonardi & Barley, 2010; Gal & Berente, 2008).

Based on a historical example of the introduction of the fluorescent lamp between 1938 and 1940, Bijker (1995) explains the importance of sociotechnical interaction in the development of technological artifacts. In a period of two years, the fluorescent lamp transformed itself from a low intensity lamp for coloring purposes to an energy saving lamp to high intensity daylight lamp. The notion of sociotechnical influence is presented by Bijker (1995) as follows:

> *"Technology and society are both human constructs. Technology is created by engineers working alone or in groups, marketing people who make the world aware of new products and process, and consumers who decided to buy or not to buy and who modify what they have bought in directions no engineer has imagined. Technology is thus shaped not only by social structures and power relations, but also by the ingenuity and emotional commitment of individuals. The characteristics of these individuals, however, are also a product of social shaping. Values, skills, and goals are formed in local cultures, and we can therefore understand technological creativity by linking it to historical and sociological stories" (p.3).*

In the context of mapping and GIS technology, Walsham (2002) and Walsham and Sahay (1999) showed that implicit cultural assumptions and values embedded in the technology were the main reasons why Indians rejected maps developed by American and European foresters and land- management experts using GIS systems. The GIS system was proposed and designed for the Ministry of Environments and Forests and brought to India after its development. Indians refused the maps because their frames and conceptualization of space differed from the Western world (Walsham and Sahay, 1999). The authors suggested that Indians rejected the maps because they conceptualize space differently than Westerners. In contrast to Western societies in which space is an abstract and objective concept and it is assumed that users are comfortable with maps inscribed into the technology, Indians concept of space are experiential or subjective and maps have been mainly paper-based rather than electronic (Walsham and Sahay1999). For the Indian culture, space is inherently attached to place and maps are not common cultural artifacts used in their daily lifestyle activities such as travel. In addition, Indians also assumed that because of the multilayered nature of GIS systems, where data on different characteristics are brought together as overlays in the same map-based system, management issues would be addressed in a coordinated way. However, in India, the management of land resources (e.g. agriculture, forest, wildlife) is compartmented and handled in relative isolation by different agencies. As a result, most of the projects investigated by Walsham and Sahay (1999) at district-level administration were not accomplished and the establishment of a GIS imitative was not fully achieved.

Ghose and Elwood (2003) exemplify the importance of contextual factors and complex relationships as important determinants in shaping access to spatial data as well as enhancing and limiting PPGIS endeavors in the United States. In the City of Milwaukee, for instance, PPGIS and citizen participation initiatives have been supported by a dense network of institutions that have provided technical and analytical expertise for GIS access and spatial analysis, as well as for neighborhood revitalization planning. Data sharing and data development activities between these supporting institutions and the City of Milwaukee have strongly enabled the development of PPGIS initiatives. Citizen participation has been facilitated by a larger number of well-established community organizations actively engaged in their own neighborhood-level improvement efforts. In addition, the presence of alternative avenues for community organizations to access PPGIS and use their spatial analysis to leverage new opportunities has been enabled through the dense network of actors providing alternative GIS support in Milwaukee. Nevertheless, divergent opinions between the many government and non-governmental about of what constitute citizen participation, the necessary structures to promote participation and access to geographic data have restricted the implementation of PPGIS initiatives in the region. As an example, while community organization staff expected that their role at public meetings about neighborhood revitalization projects undertaken by the Department of City Development as community representatives preseting the neighborhood's issues and concerns, city department members expected that they would provide formal presentations of their neighborhood's issues and concerns but supported with neighborhood statistics, thematic maps, and spatial analysis. In this case, opportunities for improvement, according to Ghose and Elwood (2003), could include development of collaborative efforts between community groups and intitutions to suppport PPGIS implementation and to insert their spatial analysis into the local planning arena.

Recently, differences in framing between model developers and policy makers about the role of models in water resource management represented a key constraint in the implementation of innovative water policies for integrated water resource management in Europe (Pahl-Wostl, 2007). While model developers strongly supported the development of integrated catchment models to understand complex management of river basins, policy makers were concerned with the possibility of multiple management scenarios and with the high degree of uncertainty of prediction models. The development of recent actions such as interactive workshops seems to be bridging this gap between science and policy in the European water management context. According to Pahl-Wostl (2007), interactive workshops are providing a unique opportunity for mutual understanding of model developers and policy makers' perceptions on roles of models of integrated water resource management and establishing a closer link between stakeholder participatory processes and model development. The mutual interaction between experts, practitioners and potential users of spatial information technology is a key aspect for developing more demand-driven, user-friendly and integrated applications in public participation geographic information systems (PPGIS).

The adoption of a more sociotechnical approach has changed systems development from a 'technology-push' to a 'demand-pull' view expanding the definition of an information system, such as GIS, to include not only hardware and software, but also its users (Reeve & Petch, 1999). Within the PPGIS field, Sieber (2006) states that four major themes constitute a framework for evaluating current PPGIS activities: (i) place and people, (ii) technology and data, (iii) organisational processes, and (iv) outcome and evaluation. According to Sieber (2006), different contexts (place) and multiple stakeholders' perspectives (people) frame PPGIS as a highly localised activity. For instance, she exemplifies that while different legal structures for copyright and information access enable easy dissemination of census data in countries such as the United States, it also restricts its diffusion in countries such as Canada. In contrast to the US in whose information is considered to be owned by the people and data is offered for the cost of dissemination, Canada as a consequence of its British colonial past recognizes government information (and the value added by purchasers) as the property of the Crown. Likewise, distinct organisational processes determine differentiated levels of coordination within an organisation or network, the availability of GIS technology, data, and expertise. Therefore, such a contextualist approach considers that other contexts of a technology (e.g. economic, social, and political) are also important to its development and design (Bijker 1995; Elmes *et al.*, 2005). Therefore, it is important to identify the users, their needs, and the contextual conditions within which the technologies are embedded (Davies and Medyckyj-Scott, 1994; Weick *et al*., 2005).

Despite advancements in the PPGIS field, more research about the practical impacts and relevance of technological systems such as GIS is still needed (Balram & Dragićević 2006; Campbell & Masser, 1995). The proposed theoretical framework captures important elements of the sociotechnical theory with the purpose of better understanding the different contextual factors (or frames) that influence the participation processes and use of spatial information and GIS tools in three practical case study situations located at the dry tropical coast (North Queensland, Australia).

An Analytical framework for integrating public participation, spatial information and related technologies in natural resource management

In this research, a theoretical foundation bounded by concepts and assumptions from Social Constructivist (De Man & Van den Toorn, 2002; Leonardi & Barley 2010; Russell *et al*., 2010; Sahay & Robey, 1996) and Sensemaking (Dervin 1998; Weick *et al*., 2005; Davidson, 2006) approaches set the boundaries for understanding and interpreting socio-contextual factors in the use of spatial information and GIS as potential ways to strengthen stakeholders' participation in NRM. The framework constitutes an analytical approach for organizing ideas, processes and key factors to provide conceptual clarity and procedural guidance. The framework represents the author's interpretation and synthesis of the literature reviewed and conceptualisation of the problem undertaken by this research. It is, however, limited by its author's beliefs and interests.

The proposed framework builds upon earlier efforts aimed to characterize and understand the diversity of contextual factors promoting and restricting the development of public participatory approaches that use spatial information GIS technology as a means of engaging and communicating with stakeholders in decision making processes. The review and synthesis of background literature on existing frameworks on public participation, geographic information and related spatial based technology provided valuable insights for the development of the conceptual model used in this research. The framework complements existing lines of thought set out by PPGIS proponents by incorporating elements of social constructivist and sense making which approaches underlie the mutual influence of social and technological contexts.

Contrary to traditional technological deterministic approaches which focus on the technical and economic aspects and endow technology as shaping the social context, the proposed framework follows a more contemporary scope by considering that technological artifacts can be shaped towards and influenced by social goals and needs. In this sense, the framework is similar to recent approaches on technology assessment in social contexts. Such approaches recognize the mutual shaping of technology and context and the need to consider people's needs and concerns proactively from the beginning ('upstream') of the process instead of after ('downstream') technological development (Russell *et al.*, 2010). The basic assumption underlying this approach is that "*information technology does not directly 'impact' upon the social system in which it is developed and used. Rather, information technologies are subject to social interpretation by actors implementing and using them, and the social meanings of technology affect the manner in which they are implemented and used*" (Sahay & Robey, 1996: 256).

The theoretical framework presented in Figure 2.5 encompasses sets of constructs, processes concepts and frames embedded by a specific contextual situation. The core constructs of the framework, public participation and the use of spatial information and GIS technology, are shown as being influencend by all the other components. It is assumed that the interaction between multiple contexts (social, institutitional, technical) shape a specific situation at the same time that they influence and are influenced by cultural (cultural desirability) and organisational (organisational feasibility) processes. Such processes, in turn, are shaped by the key concepts and frames of meaning which are conceived in different ways by distinct social groups. The arrangements in which they do this are related to their perceptions and assumptions about a specific context. Overall, all components of the framework are interconnected and mutually influence each other. These reciprocal linkages and presumably influences between the framework components is an ongoing process as the arrows in Figure 2.5 denote. Further explanation of the framework components is provided as below.

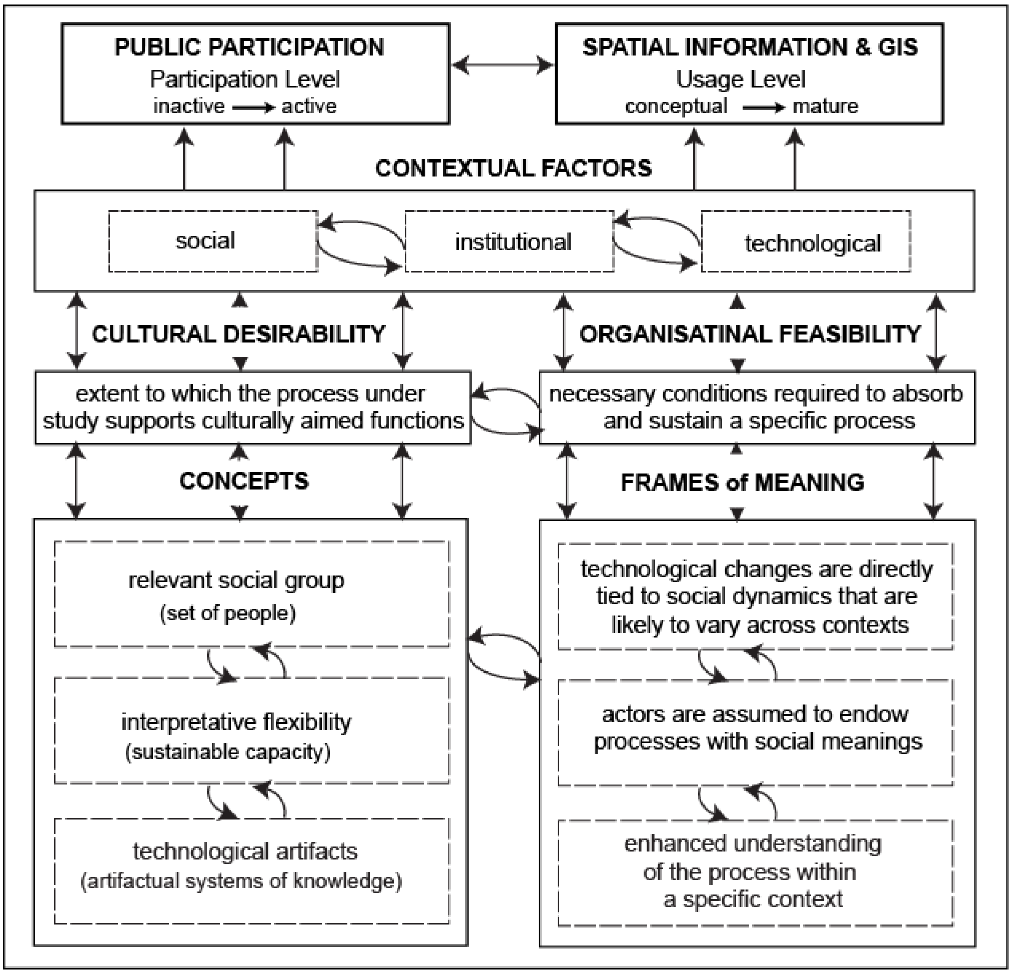

Figure 2.5. Theoretical framework underling the mutual influence of social and technological contexts

Constructs constitute the main elements of a theoretical framework or hyptheses (Nyerges *et al*., 2002). In the proposed analytical framework, public participation and the use of spatial information and GIS technology represent the core constructs of the research. Both constructs were broadly defined and discussed in earlier sections of this chapter. In the current study and proposed framework, *public participation* is defined as the main strategy (e.g. agenda-setting, decision-making, and policy-forming) and mechanim (e.g. public consultation, advisory committees) undertaken to engage and communicate with the public about natural resource management issues (e.g. rezoning marine resources, water quality). *Spatial information and GIS technology*, the second core construct of the framework, refers to any technology or related products and devices associated with a geographic location-specific position and uses spatial tools to collect, manipulate and visualize spatial data.

The constructs lie along a scale represented by four levels of participation (inactive, peripheral, latent, active) and usage of spatial information and GIS (conceptual, infancy, growing, mature). For example, in an inactive level (non-participation) of participation people do not take part in any of the stages of the decision making process, whereas in the active level (full participation) people are involved early in the decision making process during the conception of goals, design and implementation of management actions. In regard to spatial information and GIS technology, levels of usage vary from conceptual (not used), which means there is no use of geospatial tools and related information, to mature (high use) where data and technology are integrated into activities and status of usage is fully implemented and operational. Specific exemples of the different levels addressed in this research are further provided in Chapter 7.

Contextual factors encompass a complex array of issues related to the surroundings, circumstances, environment, background, or settings which determine, specify, or clarify the meaning of an event or situation within a particular context. As stated by Ghose and Elwood (2003: 19) "*context is not a singular unified factor, but must be assessed as a complicated set of interrelated factors*". For the purposes of this research, contextual factors are distinguished as *social* (including cultural, economic and environmental), *institutional* (political, organisational) and *technological (technical) aspects* that influence public participation, shape the use of spatial information and geographical information technology, and determine the extent to which PPGIS initatives are supported. Likewise, *social* is used to refer to behavior, perceptions, responses and interaction of individuals to the surrounding circumstances and it includes cultural, economic and environmental factors. Examples include, but are not limited to people's reactions to, management strategies, feelings of distrust and need for improved relationships across organisations and stakeholder groups. *Institutional* relates to the array of political mechanisms and organisational structures governing the design and implementation of management actions and the decision making process including short-term funding schemes, lack of personnel capacity, mismatch between agendas and timelines, organisation structure openness to the decision making process. *Technological* includes not only the physical and technical aspects of GIS and spatial information but also issues related to their purpose and usefulness such as data accuracy and scale, software complexity, updated information, and data delivery interfaces.

The framework distinguishes two linked **processes:** *cultural desirability and organisational feasibilit*y. Desirability and feasibility are interrelated processes driving and shaping the implementation of PPGIS initiatives within a specific context.

- *Cultural desirability* refers to the extent to which participatory process and GIS technology supports culturally aimed functions (e.g. communication and information sharing, strategic planning, operational planning and management) and responds in a culturally appropriate and acceptable manner. That means, although the introduction of GIS is organisationally feasible it might not intersect with and address cultural critical problems and thus face resistance to its adoption (Sahay & Robey, 1996; De Man & Van den Toorn, 2002).
- *Organisational feasibility* indicates the necessary organisational conditions (e.g. financial and technical resources, infrastructure, skills) to sustain a specific process, such as public participation and the use of geospatial technologies and maintain organisational functions (e.g. support to strategic planning, communication, monitoring and evaluation) (De Man & Van den Toorn, 2002). Feasibility relates to whether a new condition/process will fit into the organisation while meeting the desired goals and objectives.

The framework is structured by three main **objects or concepts**: *relevant social groups, interpretative flexibility/adaptability and technological artifacts* (Bijker 1995; Sahay & Robey, 1996).

- *Relevant social* groups are usually defined as *"a set of people who share a common geographical space, or occupy the same functional boundaries"* (Sahay & Robey, 1996: 259). In the field of the social construction of technology, socially relevant groups are characterised based on similarities among interpretation of technology including institutions, organisations, as well as unorganised groups of individuals (Pinch & Bjker, 1984; Bijker *et al.,* 1987; Harvey and Chirsman, 1998). Relevant social groups drive the need for technological innovations interpreting and redefine existing technologies and adapting them to their purpose (Bijker, 1995; De Man & Van den Toorn, 2002).
- The second concept, "*interpretative flexibility and adaptability,* is the *"capacity of a specific technology to sustain the divergent interpretations of multiple relevant groups"*

(Sahay & Robey, 1996: 260). It is a "*function of the different actors and socio-historical contexts implicated in its development and use*" (Orlikowski, 1992: 405). Within the PPGIS context, for instance, it might represent the coupled adjustability of the participatory process and geographic information system to respond and incorporate needs and expectations of different stakeholder groups.

- *Technological artifacts*, the third concept, characterize the role played by technologies in a specific process which is organized and embodied around knowledge, experiences and interactions with social agents (Orlikowski, 1992). It recognizes that technologies are not neutral. Instead, people design and adopt technologies with objectives in mind and they construct alternative meanings for the technology use. As "*artifactual systems of knowledge, information technologies acquire social meanings that affect the consequences of the technology*"(Sahay & Robey, 1996: 279). Therefore, the meanings associated to a technological artifact, which in the case of this research refers to geographic information systems and related products, are framed by the role of technology in terms of a mutual interaction between social groups and technology, and hence as both structural and socially constructed.

The other compartment of the analytical framework is composed of **frames of meaning** which comprise the overall boundaries composed of assumptions, beliefs, and expectations that people apply to a specific process shaping its implementation and functionality (Orlikowski & Gash, 1994; Sahay & Robey, 1996). Overall, similar frames are likely to be aligned within a relevant social group because members share common relationships and experiences with a particular phenomenon. Nevertheless, each group's frame may differ from those of other groups. As exemplified by Sahay and Robey (1996), developers and users of information systems typically construct different frames of meaning because their interactions with a particular application differ and they come from different social positions, educational backgrounds, historical circumstances, and interests.

- The first frame states that *technological changes are directly tied to social dynamics that are likely to vary across contexts*. Usually, "*the consequences of a technology such as GIS are assumed to be indeterminate because of the inherently unpredictable nature of the social processes*" (Sahay & Robey, 1996: 258). Thus, the social (and other) impacts of a technology-related process can be caused as a direct result of the technology, or can be caused indirectly through the complex interaction between social, institutional and technological effects (Russell *et al.*, 2010). Consequently, a better understanding of the societal outcomes of a particular technological development requires an understanding of the changing social setting (in which the technology is embedded) and cannot be gained from a limited focus on the technology and its direct effects (Williams & Edge, 1996).

- The second frame reveals that different *people (actors) embrace technology with social meanings* that can shape the implementation and subsequent use of information systems. Technological frames of meaning are usually shared within a relevant social group whose relationships and experiences with specific technology are similar. However, it might also differ between different groups, such as technology developers and users of information systems because their interactions with a particular application are different (Leonardi and Barley 2010; Gal & Berente, 2008; Orlikowski & Gash, 1994; Pahl-Wostl, 2007; Sahay & Robey, 1996). In other words, people make sense of new technologies by drawing on and transferring ideas and concepts from familiar domains to a new situation. Yet, *"some of their understanding of a technology must inevitably emerge as they encounter its constraints and affordances in the here and now"* (Leonardi and Barley 2010: 15).
- The third frame infers that an '*enhanced understanding of the process within a specific context'* provides a more tailored identification of those elements that comprise the implementation of public participation initiatives and use of information technology. It assumes that there is not an 'umbrella' ideal condition applicable to all situations. That means, the use of GIS to support public participation in a specific cultural and organisational structure is not simply transferable to other situations. However, it might be possible to find sufficiently similar conditions to enable meaningful sharing of learned experiences (De Man & Van den Toorn, 2002).

The analytical framework grounded on a social constructivist approach is useful to understand the mutual influence of social conditions and technology in shaping each other (De Man & Van den Toorn, 2002; Harvey & Chrisman, 1998; Leonardi & Barley 2010; Russell *et al*., 2010; Sahay & Robey, 1996; Sieber, 2006). It suggests that technology design and use is an open and adaptive process that can produce different outcomes depending on the social circumstances of its development and application. This mutual influence is also an essential component of the sensemaking which involves the use of context to understand how people look at a situation and what sense they make of the use of the phenomenon under study (Dervin, 1998; Leonardi & Barley 2010; Weick *et al*., 2005).

The framework's usefulness is illustrated in Chapter 7 by the application of specific findings from three practical case study situations (Chapters 4, 5 and 6) located at the Queensland dry tropical coast (Australia). To address the extent to which the contextual aspects support PPGIS initiatives in the context of the case studies, the framework is first synthesized into four possible PPGIS scenarios (Fig. 7.2) based on the existing mechanisms and participation strategies representing the current status of the intersection between public participation with spatial information and GIS initiatives. The framework is then expanded (Figs.7.3, 7.4 and 7.5) considering the findings of the three case studies presented in Chapters 4, 5 and 6.

The proposed analytical framework contributes towards a better understanding of public participation processes and the interaction between users and with spatially-referenced data and geographical information technologies by incorporating a variety of stakeholder groups (recreational fishers, coastal managers, government agencies, industry, landholders, science providers, community-based organisations), realistic management issues (rezoning GBR, water quality, emerging geospatial technologies) and scales (catchment, coastal and marine systems). An enhanced understanding of the contextual (social, institutional and technical) aspects that influence public participation and shape the use of spatial information and geographical information technology can support the development of more appropriate ways of promoting public participation initiatives as well as interacting, communicating and learning with GIS technology and spatially-referenced data. The proposed framework is applicable for other situations as it provides a coherent and structured way of synthesizing different contextual factors that influence participation and shape the meaningful use of spatial information and related technologies in the management of coastal resources.

2.4 Chapter Summary

Public participation and coupled spatial information technology is a multifaceted issue framed around complex interdependencies between a range of social, technical, cultural and political issues. Its definition co-evolves with context and the level of public participation aimed to be achieved. Further research involving a case study approach is required to explore and better document different contexts and to determine the full range of potential pros and cons of combining public participation with spatial information and related technologies. Specific issues to be addressed include the need for better definitions of what is meant by ‘public’ and ‘participation’ in different contexts, identification of different ways in which spatial information and GIS technology are presented to and used by key stakeholder groups, and the extent to which such tools support traditional means of participation.

Although much progress has been attained in the PPGIS arena, the integration between GIS, other geo-information, and public participation is still not well understood. There are still substantial gaps to be addressed, including better defining what ‘public’ and ‘participation’ means in the PPGIS field, and among the different interested parts involved. Additionally, geographic information technology has been incorporated into decision making processes without a local-based context and without truly understanding its socio-cultural and institutional implications. However, the collaborative use of GIS has produced technically oriented ideas and methods for PPGIS. These include the development of more user-friendly interfaces, network access to GIS, use of GIS as a communication medium, public access to digital data archives, and the inclusion of groups often marginalised by the costs or expertise requirements of information technology.

The linkages between ‘participation’ and ‘access to information’ are a blurred frontier with important gaps still to be addressed including the identification of the information access-participation relations in a local context, analysis of constraints and opportunities created by the use of geographic information and related technologies, and investigation on more practical and real experiences. This also involves a better understanding of the usefulness and users’ needs encompassing basic mapping requirements to more advanced geographic information technology and spatial data.

Therefore, it is necessary to document evidence on how resource users and non-experts are making use of spatial data and geographic information technology. This thesis aims to contribute to the understanding and advancement of the public participation GIS field by investigating the contextual factors and needs that are shaping the extent to which public participation, spatial information and related technology have been developed in three practical NRM situations in the tropical coast of the Great Barrier Reef. The next chapter will present the research approach and methods used to achieve this goal.

Chapter 3

RESEARCH METHODOLOGY

Abstract. This study examines the extent to which public participation processes and geospatial tools have been developed in practice for the management of natural resources in the tropical coast of the Great Barrier Reef. This chapter begins with an overview of the research approach and methods used to investigate public participation and the use of spatial information and geographic information systems (GIS) as means of engaging and communicating with stakeholders. Data collection involved a combination of qualitative and quantitative data collection techniques (e.g. semi-structured interviews, self-completion questionnaires, participant observations, and document analysis). Limitations and potential bias are also addressed. The section concludes with an overview of the study's validity and reliability.

3.1 Research Design

This chapter details the overall design approach, methods and data collection instruments used in this research. A qualitative approach based on an exploratory methodological approach and a multiple case study research was considered appropriate given the small amount of prior empirical information on this topic (Denzin, 2005). An outline of the main research design steps is presented in Figure 3.1.

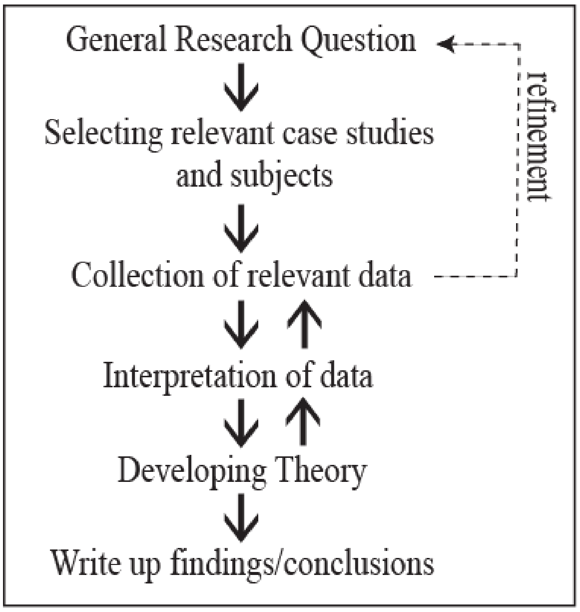

Figure 3.1. Outline of the main research design steps (Adapted from Bryman, 2004: 269).

Although no specific hypothesis was established, the research is premised on the assumption that improved access to information (including spatial data and technology) in an isolated and fragmented way is not sufficient to support better informed decisions in natural resource management. In addition, public participation processes and the use of geospatial information and related GIS technology are shaped and influenced by complex linkages between social, institutional and technical aspects.

The main advantage of an exploratory approach is its flexibility that provides an opportunity to collect detailed information of case studies and to develop a deeper understanding of the phenomenon under investigation. Findings of an exploratory case-based research methodology are not statistically generalisable to other populations or samples. Nevertheless, qualitative findings may be generalized in a different sense. Exploratory research provides opportunity for theoretical generalisation where findings are extrapolated in relation to their theoretical application to other contexts or situations which are comparable to that of the original study (Bernand, 2002; Brannen, 2005; Yin, 1994). A comparative parallel between contexts, attributes or variables is recognized at a conceptual or theoretical level and between the case or situation studied and another case or situation.

This study uses an exploratory research combining an inductive-deductive approach for collecting and analysing data, and interpreting the research findings. This approach complemented the research questions by allowing the contextual factors (or frames) that influence the phenomenon under investigation to be integral to the process of deductive thematic analysis while allowing for themes to emerge direct from the data using inductive coding (Fereday & Muir-Cochrane, 2006).

A combined inductive-deductive approach is often used as a reasoning strategy in conducting qualitative research. The former (inductive) involves externally oriented strategic activities of an explorative character directed at strategy creation while the latter (deductive) includes more focused actions aligned with the previous knowledge and existing theory (Thomas, 2006). In summary, an approach based on inductive data moves from the specific to the general, so that particular instances are observed and then combined into a larger whole or general statement. Conversely, a deductive approach is based on an earlier theory or model and therefore it moves from the general to the specific. These two paths are not necessarily mutually exclusive (Ali & Birley, 1999). Instead, an examination of the development of problem solving may reveal that inductive processes are primary during one phase, deduction at another and some combination at still another phase (Ali & Birley, 1999; Thomas, 2006).

In this research, 'deductive approach' is used to refer to the application of pre-existing knowledge, established theories or frameworks to the data, whereas 'inductive approach' refers to strategies that mainly use detailed analyses and interpretation of raw data for deriving findings and allowing the theory to emerge from the data. For example, a combined inductive-deductive approach is used for the coding analysis process. A deductive strategy was adopted in the 'a priori-coding' phase to deductively organise an initial list of codes and categories identified from the analysis of the secondary data from existing literature and theoretical frameworks during the literature review and document analysis. In the second phase of the coding process ('post-coding'), subcategories of codes were inductively derived from analysing empirical findings of the data (e.g. notes of the workshops, observation-based field notes, transcriptions of face-to-face interviews). The coding process is presented in Section 3.1 and detailed in the data analyses section of the case study chapters.

Three case studies and key stakeholder groups have been selected to investigate and document the extent to which public participation processes and geospatial tools have been developed in practice in the tropical coast of the Great Barrier Reef. A brief description of the case studies used in this research is presented in Section 3.2. The case study research is an appropriate approach for situations which requires emphasis to a location, such as community or organisation (Bryman, 2004; Creswell, 2003; Yin, 2003). Moreover, case studies are the recommended approach in situations where there is no opportunity to control or manipulate the variables under investigation, and when the focus is on explanations and analysis of situations or events (Denzin, 2005; Gray, 2004). Multiple case studies strengthen the results by replicating the pattern matching, thus increasing confidence in the robustness of the findings and supporting theory building (Amaratunga & Baldry, 2001). The use of multiple cases in this study underlines the complexity of the topic under investigation and develops the empirical evidence to support and advance existent theory.

Sampling Strategy

This study employed a combination of *purposive and random sampling* approaches according to the specific nature of each case study (Patton 2002; Bernard, 2002; Bryman 2004; Gray 2004; Nastasi & Schensul, 2005; Silverman 2006). The sampling plan was flexible and evolved with the research needs, and participants were selected mainly through a *purposive approach* (Sahay & Robey, 1996; Bryman 2004). Purposive sampling is a form of non-probability strategy in which the selecting units (e.g., individuals, groups, institutions, events) are deliberately selected according to the purposes of the study. This strategy was adopted for two of the three case studies of this research. In one case study participants were randomly selected. In order to minimize repetition in this thesis, specific descriptions of data collection and analysis will be detailed for each case study in Chapters 4, 5 and 6.

Overall, a small number of initial key informants were selected through liaison with case study partners and also through direct observation at stakeholder meetings. Additionally, more informants were added during interviews based on the advice of those being interviewed until redundant information was collected and a comprehensive account of issues and problems had been compiled (Measham, 2003). This type of liaison and observation represented an essential stage for a non-local and non-English native speaker researcher to understand the meaning of the context and generate rapport (Bernard, 2002). The size of the sample was not pre-determined and the sampling process was complete when theoretical saturation was achieved (Bryman 2004; Gray 2004).

Data Gathering

This exploratory research utilised both qualitative and quantitative data collection methods. The mixed methods approach was composed of three main phases and it involved multiple sources: 1) literature review and document analysis, 2) participant observation, and 3) workshops-group discussions, surveys and interviews (Fig. 3.2). The triangulation of multiple primary and secondary data collection methods contributed to a better understanding of the different levels of information about the phenomenon under study (Denzin, 2005; Bryman, 2004; Patton, 2002; Seale, 2004). e

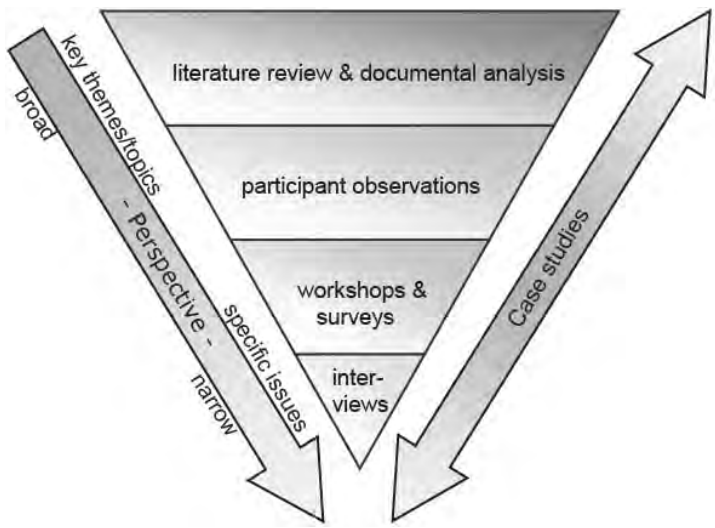

Figure 3.2. Components of the data collection design.

The collection of data from multiple qualitative and quantitative sources of evidence has several advantages such as providing lines of inquiry through data triangulation, allowing a broader range of concepts and issues to be investigated, and strengthening case study findings and improving validity (Rockloff, 2003; Yin 1994). Therefore, the combination of qualitative and quantitative techniques also provided mutual enhancement of the research's validity (Jardine, 2003). Additionally, practical coastal management issues and stakeholders' relationships were examined through the investigation of realistic decision making initiatives at different spatial planning scales.

A **literature review** and **document analysis** was carried out to provide background and context to the research. Difficulties in formulating pre-determined categories were obvious because of the multiple meanings attributed to the term 'participation', the complexity of goals of participation and the wide range of activities associated with participation. The literature review had two phases. During the first phase, which occurred prior to the period of intensive data collection field work, the literature on public participation and GIS was reviewed. In line with an inductive-deductive approach, the literature search on the key emergent theme was undertaken after data collection and initial data analysis (Seale, 2004). The second phase of the literature review was a comprehensive document analysis on coastal management policies and practices (e.g. coastal and catchment management programs, legal-institutional-policy framework and tools) identified key themes and issues relevant to public participation and spatial coastal planning.

The next stage of the research can be characterised as the phase of **immersion in the field setting**. This stage was primarily guided by the proposed analytical framework and previously derived research questions. The field work was conducted from October 2006 to June 2008. The primary sources of data were: (i) participation in the setting and direct observation at stakeholders' meetings of the selected case studies, (ii) in-depth semi-structured interviews with key informants, (iii) mail and online surveys, and (iv) workshops.

Observing participants was a fundamental aspect of this research. Participant observation at stakeholders' meetings of the selected case studies represented an efficient way to explore issues and concepts arising from the literature review and document analysis. Focused observations on issues of representativeness, power relations, communication channels, interests, conflicts, and inputs from the parties related to management decisions were analysed for the varying spatial planning scales provided by the different case studies. Participant observation also enabled the cross validation of data surveys and interviews as well as the full observation of the dynamics of the meetings and of the participants' perspectives and interactions. Participant observations at stakeholders' meetings were essential to build trust between the researcher and the target population of the study.

Workshops represented an important data collection tool in this research. In some cases, rather than organising meetings especially for this research, workshops followed existing stakeholders' meetings. The main rationale for integrating existing meetings was twofold: (1) to minimise inconvenience to participants, and (2) to minimize costs to the researcher.

Open-ended and semi-structured interviews, along with literature review, document analysis and field observation, were complemented with workshops and closed-ended mail and online surveys. A list of discussion topics, rather than structured questions, was prepared to guide the interview process. Both interviews and surveys followed a flexible and adaptive format which allowed the inclusion of new information and modification of existing questions according to the flow of the data collection process.

The linkage between qualitative and quantitative data allowed verification or corroboration of data via triangulation (Bryman, 2004; Gray, 2004; Seale, 2004). The degree to which the various primary sources of data were collected for each case study is presented in greater detail in the relevant chapters. At this point, it is important to highlight that the unique contributions of the case studies used in this research required the use of different data collection methods.

In Chapter 4, a combination of participant observation, interviews, short-surveys and workshops were used to investigate the main drivers and limitations of participation and needs for spatial information in water quality management in the Burdekin Dry Tropics NRM region. The second case study (Chapter 5) required an interview map-biography method and data validation at fisher's meetings to assess the effects of increase in no-take areas to spatial displacement of recreational fishing effort and aggregation within the GBR Marine Park. Interviews, online surveys and workshops were the main methods used by the third case study (Chapter 6) in order to address the extent to which the deployment of geospatial technologies, such as the sensor network, and the delivery of real-time data can best suit managers' and decision makers' needs by providing timely and useful spatial data.

Data Analyses

Systematic qualitative and quantitative techniques were used to analyse data (Weber, 1985; Denzin and Lincoln, 2000; Patton, 2002; Gray, 2004). The data analysis was a flexible and iterative process in which data**,** partially analysed during the collection process, allowed for adaptation of the data collection techniques (Nastasi and Schensul, 2005). The data analysis process was mainly guided by a **Grounded Theory** approach by prioritising the data and the field under study over theoretical assumptions (Strauss and Corbin, 1998). Following Grounded theory, studied subjects to be studied are selected on their relevance to the research topic and they are not selected for constructing a (statistically) representative sample of a general population (Flick, 2006; Nastasi & Schensul, 2005; Rockloff, 2003).

The analysis of **qualitative data** involved coding (indexing) and thematic analysis of documents, transcripts and write-ups, and computer files for analysis using a qualitative data software program QSR NVivo Version 7.0.247. Coding consisted of using tags or labels (codes) for assigning units of meaning to descriptive or inferential information collected during the study (Bernard, 2002; Bryman, 2004). The coding process was composed of two phases, 'a priori-coding' and a 'posteriori-coding'. 'A priori-coding' phase consisted of a pre-analysis process of organising the secondary data collated during the literature review and document analysis. The initial list of codes was derived deductively from the key patterns and themes from the literature review and document analysis. In the second phase, a 'post-coding (posteriori)', the coding scheme initially developed was revised, refined and consolidated into subcategories. Subcategories of codes derived from empirical findings of the data and organised in meaningful categories by analysing written records (e.g. notes of the workshops, observation-based field notes, transcriptions of face-to-face interviews) and checking for consistency.

The specific actions taken on the data included (Sahay & Robey, 1996; Strauss & Corbin, 1998):

i. *(open) coding and splitting* (development of a open coding scheme to provide a means for identifying and later combining statements with similar meanings);
ii. *formation (axial coding) of themes* (theme is defined as a unifying idea representing the interpretations found in multiple coded segments. Themes were developed by integrating the split data on the basis of similarity in the meaning of concepts.);
iii. *aligning themes (selective coding) and producing context* (groups of codes subscribing to the themes were identified by detecting commonalities among the coded segments that made up each theme); and
iv. *deriving theoretical inferences* (development of deeper understanding of the key issues and relationships).

Quantitative data were analysed using standard statistical techniques and are fully described in the chapters relevant to each of the case studies. For instance, in testing for significance, t-tests were used on interval-scaled (e.g., continuous) variables, and chi-square tests of independence were used for nominal and ordinal variables. All tests were conducted using SPSS (Statistical Package for the Social Sciences) Version 15.0. Data for closed-ended survey questions were analysed and presented descriptively.

The Researcher's role in data collection and analyses

The three case studies required specific strategies in data collection and analyses. Although detailed information is presented in the subsequent case studies Chapters 4, 5, and 6, it is relevant to highlight at this point my role in collecting, organising, analysing, and discussing the data presented in the thesis.

In Chapter 4, I collected documents and reports, participated at stakeholders' meetings, designed the questions, conducted the interviews and surveys, and organized a group discussion session, which was conducted with the support of an experienced native English facilitator. I was responsible for data compilation, analysis, interpretation, and preparation of the final results. I developed short-feedback reports for the stakeholders' involved in this case study.

In chapter 5, I contributed with the design of the map-based interview questions and provided regular feedback to refine the questions. I designed the geographic information system (GIS) database, processed and organised the collected map-related information. I participated in the validation process of the spatial data by attending fishers' meetings and interacting with stakeholders. Finally, I conducted the data analysis and results presented in this chapter.

In Chapter 6, I designed the workshops (also conducted with the support of experienced facilitators), online surveys, and interviews. I also elaborated the two reports resulted from the workshops. Finally, I analysed, interpreted and compiled the results provided in this chapter.

Reliability and Validity

Qualitative and quantitative data require different techniques when assessing validity and reliability. The integrity of research is analysed throughout the accuracy of its findings, truthfulness about its assumptions and conclusions reached (Long and Johnson, 2000). Reliability and validity are important criteria to assure objectivity of the assumptions and findings in quantitative research (Bryman, 2004; Kirk & Miller, 1986).

The conceptualisation of reliability and validity varies among different authors writing from different methodological positions (Winter, 2000). Despite discussions about its adequacy to qualitative research and in some cases complete rejection of its usefulness, reliability and validity are becoming increasingly applied to naturalistic studies as components of credibility and authenticity (Bryman, 2004; Fossey *et al.*, 2002; Golafshani, 2003; Kirk & Miller, 1986; Seale 2004; Winter 2000).

Since measurement is not a major purpose for qualitative researchers, the conventional meaning of reliability and validity is claimed as not adequate for naturalist studies (e.g. Bryman, 2004;

Kirk & Miller, 1986; Trochim, 2006). Therefore, alternative criteria for both reliability and validity are applied for establishing and assessing the quality of qualitative research. Although a detailed discussion on the terminology of reliability and validity from both quantitative and qualitative perspectives is not the focus here, a brief example in Table 3.1 elucidates this issue.

Table 3.1. Example of the meanings of reliability and validity in quantitative and qualitative research paradigms.

	Quantitative	Qualitative
Reliability	• refers to the consistency of a measure of a concept (Bryman, 2004). • represents the degree of replicability of instruments, responses and analyses (Winter, 2000). • indicates the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions (Long and Johnson, 2000).	• refers to the degree to which the findings of a study are independent of accidental circumstances of their production (Silverman, 2006). • addresses how accurate research methods and techniques produce data (Rockloff, 2003). • describes the consistency of a measuring instrument, or the degree of consistency/dependability with which an instrument measures the attribute it is designed to measure (Long and Johnson, 2000).
Validity	• indicates whether an indicator that is devised to gauge a concept really measures that concept (Bryman, 2004). • determines whether a measurement instrument actually measures what it is purported to measure, or the degree to which an instrument measures what it is intended to measure (Long and Johnson, 2000). • defines whether the means of measurement are accurate, and whether they are actually measuring what they are intended to measure (Winter, 2000).	• represents accurately those features of the phenomena that it is intended to describe, explain or theorise (Hammersley, 1992). • the extent to which data represent the concepts of interest (Rothman, 2007). • the degree to which measures (e.g. questions on a questionnaire) successfully indicate concepts (Seale, 2004).
Criteria [a]	• internal validity	• credibility
	• external validity	• transferability
	• reliability	• dependability
	• objectivity	• confirmability

[a] Based on Bryman (2004), Long & Johnson (2000), and Trochim (2006).

Because of the multi-strategy nature of this research, considerable effort was made to address quality and minimise threats during the collection, analysis and interpretation of both qualitative and quantitative data. Firstly, a conscious understanding that the researcher is the primary instrument of data collection for qualitative information (e.g. field observations, interviews) and that, therefore, reliability (or dependability in qualitative research) and rigour of the results were related to the ability of the researcher (Nastasi & Schensul, 2005; Rockloff, 2003) is required. However, a sense of detachment and dissociation was required to analyse quantitative data (e.g. closed-ended survey questions) (Winter, 2000). Secondly, credibility (reliability) and transferability (validity) of the study findings were supported throughout an in depth-contextualisation of case studies reporting and systematic design and implementation of data collection and analysis (Table 3.2).

Table 3.2. Summary of the main procedures adopted during the research process.

	Procedure	Research Phase
Reliability	• standard methods to collect, write and analyse fieldnotes, interview transcripts, survey data, and workshop outcomes.	• data collection, data analysis
	• use of facilitator and guide protocol in workshop sessions.	• data collection
	• code index to interpretation and comparison of data codes.	• data analysis
	• use of interview probes and verbatim quotes to support data interpretation and accuracy.	• data analysis
	• design data recording sheets to guide collection and analysis of in-depth interviewing or of participant observation events.	• research design, data collection
	• multiple sources of evidence (e.g. literature review, document analysis, field observations, workshops, surveys and interviews) for triangulating findings.	• research design, data collection & analysis
	• use of databases for qualitative (QSR NVivo 7.0), quantitative (SPSS 15.0), and spatial (ESRI®ArcMap 9.2) data.	• data collection, data analysis
	• mail surveys develop by the Dillman’s Total Design method.	• research design, data collection
	• applied reliability tests (e.g. Cronbach’s alpha) of internal consistency.	• data analysis
Validity	• respondent validation (e.g. short workshop summary for comment, presentation of results at stakeholder’s meetings) and triangulation.	• data collection, data analysis
	• use of different methods (e.g. observation and interviews).	• data collection
	• continuous checking and rechecking of the data throughout the study.	• data analysis
	• detailed description of research context and assumptions.	• research design, data analysis
	• use of significance tests (e.g. t-tests to interval-scaled variables, chi-square tests for nominal and ordinal variables.).	• data analysis
	• peer debriefing of research findings and conclusions.	• data analysis

Finally, this research used multiple sources of evidence that evolved into a ‘chain of evidence’ linking the research questions to analysis and collection of data and case study reports (Patton, 1990; Gray 2004). The mixed methods approach used has contributed to the rigour of this research.

3.2 Brief Description of the Case Studies

This section will provide a brief description of, and the rationale for the selection of the study sites. The main purpose of the selection process was to gather practical situations at distinct management scales in which public participation and the use of geospatial tools (GIS) and spatial information were an important component of the decision making process. Case studies were selected from both catchment and coastal water systems in the tropical coast of the Great Barrier Reef (Figure 3.3). This region and the case studies were selected for three main aspects: 1) diversity of stakeholder groups (e.g. users of information, resource-use exploiters, and information providers) and complexity of natural resource decision making processes, 2) increasing number of public participation initiatives, and 3) current and emergent natural resource management needs for spatial information and GIS.

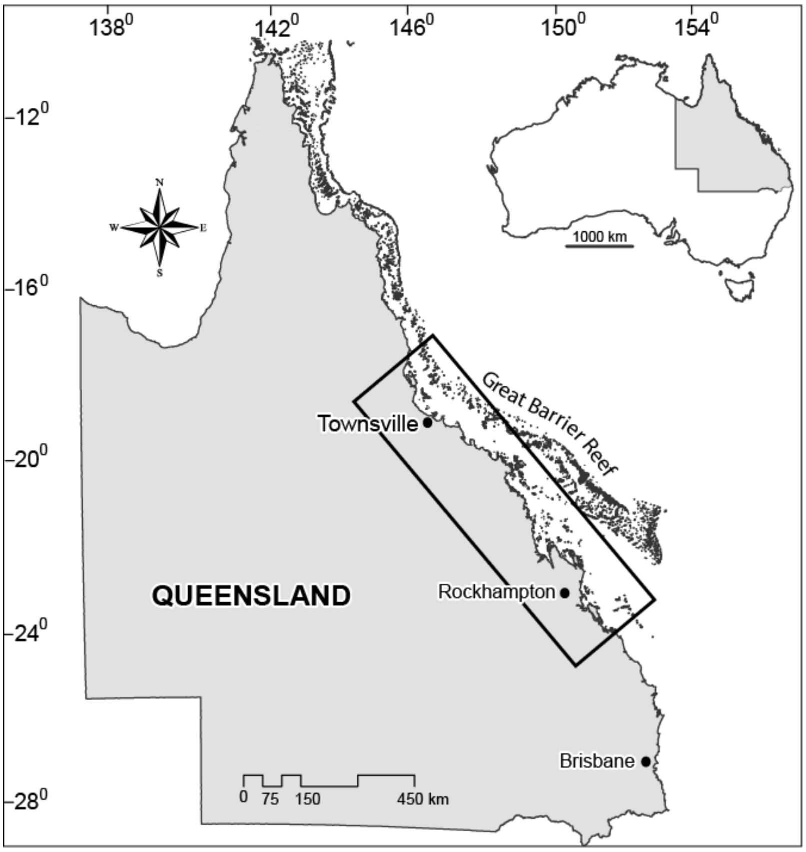

Figure 3.3. Map of studied region in the Queensland state. Case studies were located inside the marked area.

The case studies were opportunistically selected within the temporal context in which the thesis was developed accordingly to three main aspects mentioned previously. The need for an improved understanding of public participation processes, and the interaction between users and spatially-referenced data and geographical information technologies at the GBR management scale was a key factor in selecting the case studies. Overall, they represent the diversity and complexity of management from catchment-based, to coastal and marine contexts in the region (Fig. 3.4).

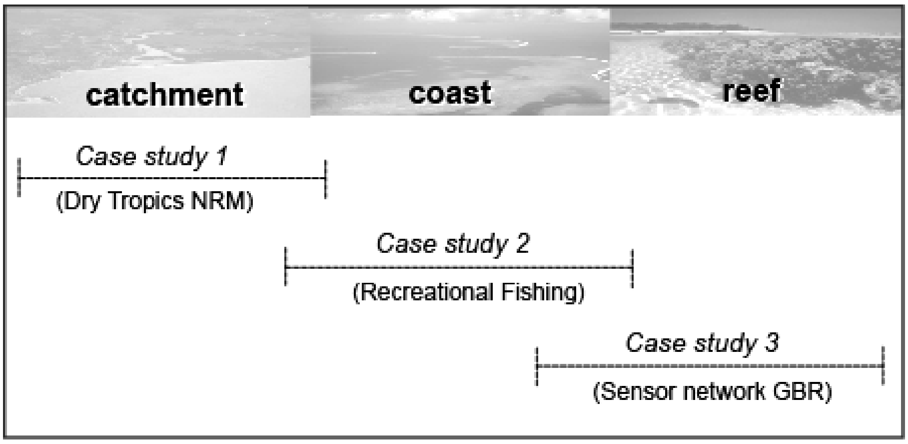

Figure 3.4. Conceptual diagram of the selected case studies and contexts.

The selected case studies provide realistic decision-making situations to investigate the socio-institutional and technical dimensions of the spatial management changes by comprehending how different users understand and make use of spatial information and geographic information tools. An outline of each case study and the specific reasons for selection are provided below, although detailed information is presented in subsequent chapters.

Case Study 1: The Role of Spatial Information and Geospatial Tools in Community Engagement and Management Processes of Water Quality in the Dry Tropics Coast NRM region

This case study is situated within a regional spatial planning context in which access to and participatory use of spatial data and geographic information tools to support more inclusive public participation in spatial planning has been a major issue in managing natural coastal resources at the regional management scale. For example, community and stakeholders' participation and spatial information strategies represent key components of the Burdekin Dry Tropics Water Quality Improvement Plan (WQIP).

The development and implementation of NRM plans, such as the WQIP, requires the engagement with a diversity of stakeholders (e.g. government agencies, industry, communities, landholders, science providers) to meet the short and longer-term requirements of target setting and to achieve pollutant reductions from land-based sources. Traditional (e.g. public forums, meetings) and innovative (e.g. website, email lists, workshops) techniques were used by the NRM body to ensure wide participation in the development and implementation of the WQIP.

Despite its increasing incorporation in the management of natural resources, spatial information and geographical techniques have been applied in decision making processes without considering the local-based context (e.g. people's willingness to participate, users' needs, socio-institutional implications). This case provides a platform to analyse the main sources of spatial information and communication tools, to assess the use of geo-information technologies to furnish access to information and to support public participation.

Case Study 2: A spatial and social assessment of management changes of the Great Barrier Reef rezoning for Recreational Fishers in Queensland

Recreational fishers are a key stakeholder group in Great Barrier Marine Park (GBRMP), and one of the major local users of resources within the park. Fishers are one of the most affected sectors of the community by the rezoning of the GBRMP in 2004. The overall aim of this project conducted by James Cook University (Fishing and Fisheries Research Centre) and CRC Reef in conjunction with the Capricorn Reef Monitoring Program (CapReef) is to investigate the social and spatial implications of the rezoning management changes of the Great Barrier Reef Marine Park Heritage Area in the recreational fisheries sector. Data has been collected since 2005 throughout several recreational fishers' communities in the coast of Queensland, including Rockhampton, Townsville, and Cairns.

The strong public participation and spatial component present in the rezoning plan and fisheries activity provided an appropriate opportunity to explore recreational fishers' perceptions and knowledge concerning public participation in fisheries and marine park management processes. Spatial information in the form of zoning map-questionnaires was the main tool used during the consultation process for collecting information from people about their use of the park and their opinions on the locations of proposed new no-take zones. Therefore, this case is also a suitable context to investigate the role of GIS and the need for spatial information by recreational fishers.

Case Study 3: Linking Science and Management in the Adoption of Sensor Network Technology in the Great Barrier Reef Coast, Australia

The Coastal Environmental Sensor Networks in the Northeast Queensland (CESNNQ) project, led by the Australian Institute of Marine Science (AIMS) and James Cook University (JCU), seeks to implement sensor network platforms to monitor coastal environments, and to provide timely and useful spatial data for managers and decision makers. Initially, the CESNNQ project aims to deploy sensor networks across an area of 400 km of the GBR in the Townville coast region (e.g. Davies Reef, Magnetic Island, Heron Island, Orpheus Island).

While the technology and infrastructure components are well-developed and understood, the utility of the sensor's network data (e.g. temperature, salinity, humidity, light, water flow, sediments) and efficient delivery of real-time information are highly dependent on stakeholders' needs and management priorities. Within this context, this research aimed to contribute to current understandings in research and adaptive adoption of geospatial technology by identifying the main drivers and barriers to an adaptive deployment of an environmental sensor network in the Great Barrier Reef coast. This case provides a realistic context to evaluate the extent to which the deployment of a sensor network and delivery of real-time data can best suit managers and decision-makers needs by providing timely and useful spatial data.

3.3 Limitations and Bias

As exploratory research, this study experienced some limitations. Firstly, inherent researcher subjectivity is inevitable in research of this nature, although reasonable attempts have been made to preserve objectivity (e.g. triangulation) and rigour (e.g. respondent validation) during data collection and analysis.

Secondly, researcher bias and the selection of variables may have influenced the outcomes of interviews, field notes and analysis. While considerable effort was made to collect a comprehensive and representative range of data from multiple sources, the specific context and settings of the research findings limits generalisation of the results. Although, the interpretations and findings drawn from this research are not necessarily applicable outside the study sites, they might provide relevant information that can be adapted and applied to similar contexts.

3.4 Ethical Issues

Consistent with university policy, this research was conducted with due consideration, approval, and compliance with official ethical guidelines (James Cook University Ethics Approval No.

H2422) (Appendix A) [1]. Participants were assured about the confidentiality of their responses and results were reported in aggregate form. All participants provided verbal or written consent for their participation (Appendix A). In addition, participation in the research process remained entirely voluntary and confidentiality of informant identity was maintained.

3.5 Chapter Summary

This chapter has outlined the theoretical foundations and the research approach used to explore public participation and the role of spatial information and GIS in furnishing access to information and to support participation in the tropical coast of the Great Barrier Reef. The methodologies, methods and techniques used to address the research questions have been explained. The research design and data analysis processes used have been described in detail. Any possible limitations to research design and data analysis have been discussed, as have ways that these limitations have been accommodated or overcome. Issues of ethics, validity and reliability have been addressed in the concluding part of the chapter. The next chapters describe and discuss in detail the three case studies.

[1] Appendices are in Volume 2 of this thesis.

Chapter
4

MAPS, SPATIAL INFORMATION AND COMMUNITY ENGAGEMENT IN NATURAL RESOURCE MANAGEMENT

Case Study 1 - The Role of Spatial Information and Geospatial Tools in Community Engagement and Management Processes of Water Quality in the Dry Tropics Coast NRM region

Abstract. The engagement with a diversity of stakeholders to meet the short and longer-term requirements of target setting and to achieve pollutant reductions from land-based sources to improve water quality to the Great Barrier Reef is a complex task. Spatial data and geographic information technology have been increasingly used as a means of engaging and communicating about natural resource issues with key stakeholder groups. Access to and participatory use of spatial data and geographic information and communication tools to support more inclusive public participation in spatial planning has been a major field of debate in natural resource management, particularly within the water quality context. This chapter explores the participation strategies and tools used to engage stakeholders in the context of the development of the Burdekin Water Quality Improvement Plan. It also addresses the extent to which mapping information and spatial technologies are used to furnish access to information and to support stakeholders' engagement in natural resource management.

Chapter 4 has been accepted for publication as: De Freitas, D.M., King, D., Cottrell. The social, institutional and technical interfaces of linked public participation and spatial information in water quality management in the dry tropics coast of Queensland, Australia. *Journal of Coastal Conservation*: Planning and Management.
De Freitas, D.M. (*in prep*). Degree and nature of public participation and spatial information in natural resource management of the Burdekin Dry Tropics Coast. Target journal *Society & Natural Resources.*

4.1 Natural Resource Management and the Water Quality Improvement Plan

The management of natural resources is continuously challenged by complex environmental processes, the diversity of stakeholders and natural resource uses, and multiple management scales (Asher, 2001; Bellamy *et al*., 2001; Cicin-Sain & Belfiore 2005; Croke *et al.,* 2007). In the water management context, conflicting interests between consumptive losses upstream (e.g. degradation of riparian vegetation) and livelihood-dependent services downstream (e.g. improvement of water quality) have resulted in habitat fragmentation, altered water flows and increased run-off (Falkenmark 2003; Jonch-Clausen & Fugl, 2001; Moss 2004).

In South America, for instance, deforestation and mining practices upstream in the Amazon River have contributed to erosion and sedimentation of terrigenous organic mater causing the alteration of natural geochemical cycles of heavy metals (e.g. mercury) and organic matter in the drainage basin (e.g. Farella *et al*., 2001; Roulet *et al.*, 2000). High levels of water abstraction by farmers in the upstream highland systems in Kenya (Gichuki, *et al*., 1998) and Tanzania (Lankford & Beale, 2007) have affected water availability downstream by decreasing dry season flows in the lowlands. In Australia, coastal marine ecosystems, such as coral reefs, have experienced the impacts on multiple land-based stressors (Hutchings *et al*., 2005; Richdmand *et al*., 2007). Land clearing (including coastal wetlands) for agriculture combined with aquaculture activities and increasing urbanisation has resulted in increased runoff and sedimentation, as well as soil acidification in adjacent marine environments (Hutchings *et al*., 2005). In Northern Queensland, the management of water quality has historically been characterised by conflicting interests involving land-based activities, mainly grazing and sugarcane farming, and the implementation of the Great Barrier Reef (GBR) water quality improvement plan.

A systematic and more integrated management approach that considers the linkages between land-use and water planning has been advocated during recent decades (Flaherty & Sampson, 2005; Mitchell, 2005; Savenije & Van der Zaag, 2008). The Integrated Water Resource Management (IWRM) approach recognises the need to address both vertical (across local, state, national and international levels) and horizontal (among different agencies) fragmentation of water management institutions (Johch-Clause & Fugl 2001; Mitchell, 2005). It also identifies the importance of increased stakeholder engagement at all levels of the decision making process as a way to ensure that different interests and needs of water users are considered (Jasper 2003; Lawrence & Deagen, 2001; Marshall & Jones, 2005).

Increased participation by different stakeholder groups and a balance of multiple interests in the decision making process has been the ultimate objective of most natural resource management programs. It is believed that better participation in natural resource management leads to increased public awareness and acceptance of outcomes, a more transparent decision making processes, and facilitates the implementation of management actions (Jonsson, 2005; Buchy *et al*., 2000). However, in practice, evidence on the type and extent of participation that is most effective is scarce, and differences in perceptions and understanding tend to be neglected (Buchy & Race, 2001).

Governance of natural resources in Australia is a shared responsibility of a three-tiered system of Federal, State/Territory, and Local governments (Bammer *et al*., 2005; Dovers, 2001; Moore & Rockloff, 2006) (Fig. 4.1). In addition, a regional tier with responsibility over natural biophysical boundaries, such as catchments has been introduced (Bammer *et al*., 2005). Overall, the management of the programs is developed through a partnership between Federal and State/Territory government agencies (Jennings and Moore, 2000). However, in practice, this institutional arrangement is constrained by overlap of policies, fragmentation of institutional arrangements, and competition between objectives and interests (Dovers, 2001; Jennings & Moore, 2000).

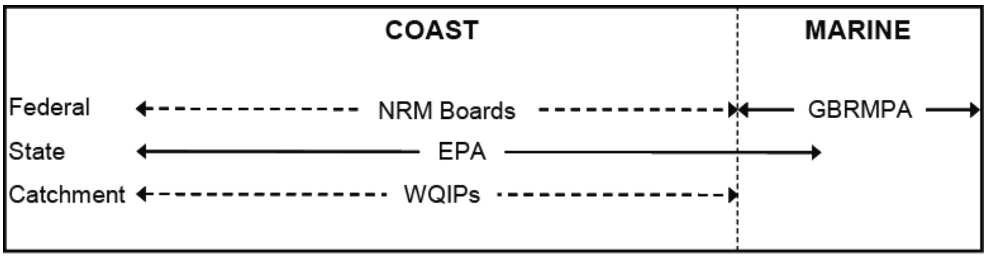

Figure 4.1. Schematic representation of government agencies involved with water source management and institutional jurisdictions in the GBR region. (Adapted from: Butler. J.R.A. *et al*., pers. comm., 24 April 2009[2], and the Commonwealth Coastal Policy 1995).

The improvement of water quality in the catchments adjoining the Great Barrier Reef (GBR) lagoon has occurred through a range of Federal and State Government programs such, as the Water Quality Improvement Plans (WQIPs) and the Reef Water Quality Protection Plan (Reef Plan). In addition, natural resource management bodies were established as a way to involve local communities in sustainable management initiatives at the regional level (Flaherty & Sampson, 2005; Roth *et al.,* 2002). However, the engagement with a diversity of stakeholders

[2] *Pers.Comm.* Butler, J.R.A., Metcalfe, D., Honzák, M., Pert, P.L., Rao, N., van Grieken, M.E., Schroers, R., Bruce, C., Kroon, F.J. and Brodie, J.E. (*In prep*). Assessing a hydrological ecosystem service linking landholders to the Great Barrier Reef, Australia: an integrated approach to economic and biodiversity trade-offs. Report to Conservation International, June 2009.

to meet the short and longer-term requirements of target setting and to achieve pollutant reductions from land-based sources to improve water quality in the GBR is a complex task. The large extent of the Burdekin catchment region, high variability of freshwater discharge and associated difficulties of setting meaningful and measurable targets, and effective stakeholder engagement of a growing and sparse population are major challenges for the development and implementation of water quality management plans (BDTNRM, 2006).

To bridge the gap between communication, information and participation, natural resource management agencies have increasingly used the visual capability of spatial decision support tools, such as GIS (Kliskey, 1995). The representation of complex environmental problems and processes through spatial scenarios and modelling techniques is a growing approach to consult and communicate with stakeholders in the decision making process (Zhu *et al*., 1998).

Spatial information and geographic information technologies have become important tools for engaging and communicating with stakeholders for the development and implementation of water quality management programs. For instance, maps and spatial information were the main tools used in the consultation process to capture stakeholders' knowledge and to identify the environmental values and uses of waterways in the Burdekin Delta, Haughton River and Abbot Bay catchments. In addition, regional NRM bodies, such as the NQ Dry Tropics (formerly Burdekin Dry Tropics NRM), are fostering the use of maps, satellite imagery and GIS software to enable stakeholder's access to and interaction with geospatial data to achieve water quality objectives and targets for reducing pollution. In the Herbert region, a catchment-based collaborative GIS facility (the Herbert River Information Centre) was established to support the management of natural resources in the Herbert River catchment by providing and allowing access to geographic information, GIS tools, and expertise (Walker *et al.*, 2002). Therefore, it is necessary to assess the benefits of spatially-referenced data and geographical information technologies to better understand how they have been used, and even more important, how they can be better used in practical decision making situations.

This chapter explores the contextual factors that shape the use of participation strategies and tools to engage with different stakeholder groups for the development of the Burdekin Water Quality Improvement Plan. It also addresses the extent to which mapping information and spatial technologies are used to gain access to information and to support stakeholders' engagement in natural resource management.

The chapter falls into five main sections. The first part outlines the geographic background, introduces the stakeholders, and describes the context in relation to the Coastal Catchments

Initiative (CCI) and the Water Quality Improvement Plan (WQIP). It further provides a brief review of key aspects of the water quality management initiatives represented by the environmental values and water quality objectives and best management practices for grazing and sugar lands. This is followed by a description of the methods employed in the data collection and explains the quantitative and qualitative components (Section 2). The research results are presented and discussed (Sections 3 and 4) and the conclusions drawn (Section 5).

Specific aims

The aims of this chapter are to:

(i) assess the current stage of public participation and document the practical lessons learned by the public engaging in water quality management in the Burdekin Dry Tropics NRM region,

(ii) analyse the extent to which spatial information and geographic information tools are used by resource managers and stakeholder groups to facilitate access to information and to support communication, and

(iii) identify information and communication factors, strategies and mechanisms that can strengthen or inhibit public participation GIS in natural resource management.

Setting the context

The study region

The study area of this chapter covered parts of the Burdekin Dry Tropics (BDT) region and surroundings, particularly the cities of Townsville, Ayr, Home Hill, Collinsville, Charters Towers, and Greenvale (Fig. 4.2). Located in north eastern Queensland, 18^{o} and 25^{o} South, and 144^{o} and 149^{o} East, the Burdekin catchment is the second largest in Queensland covering an area of approximately 133,432km² (equivalent to about 8% of the state) (Roth *et al.*, 2002). The catchment is organised around 6 major basins (Belyando, Bowen Broken Bogie, Cape Campaspe, Lower Burdekin, Suttor and Upper Burdekin) subdivided into 48 subcatchments (Dight, 2009; Roth *et al.*, 2002). The population of approximately 190,000 inhabitants is concentrated on major population centres of Townsville, Ayr, Bowen and Charters Towers (Dight, 2009; Gordon, 2007).

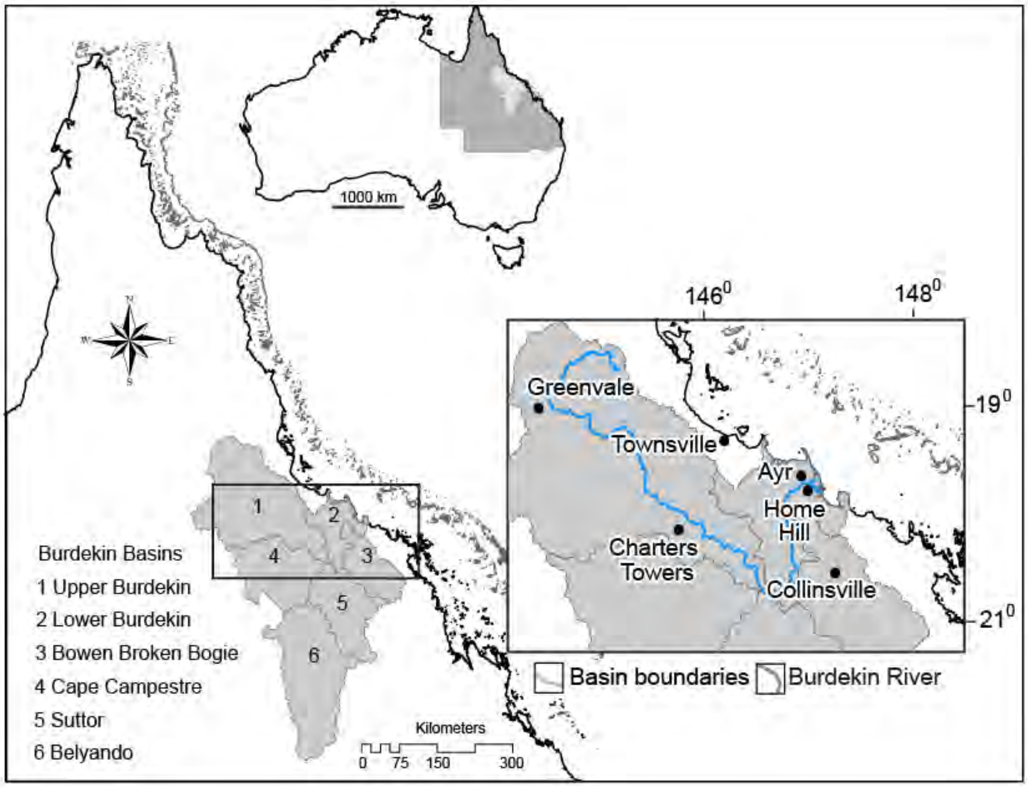

Figure 4.2. Basins of the Burdekin Water Quality Improvement Plan (WQIP) region and inset of the study area.

The region supports a wide diversity of land uses and natural assets. Cattle grazing on the native pastures of the Burdekin rangelands (Upper Burdekin, Belyando/Suttor and Bowen/Broken), and irrigated cropping, largely based on sugar production and horticulture, in the Lower Burdekin delta and floodplain are the predominant land use activities in the Burdekin WQIP region (Dight, 2009; Greiner *et al*., 2005; Roth *et al*., 2002). Other activities such as tourism, fisheries and aquaculture, mining, port and infrastructure industries are also important contributors to the region's economy. With a coastline of approximately 1300km, the Dry Tropical NRM coastal region is of particular significance. It forms part of the Great Barrier Reef World Heritage Area (GBRMHA) and encompasses a variety of notable conservation values including seagrass, wetlands, fringing reefs, marine turtle nesting and fish nursery areas (e.g. Brodie *et al.*, 2001; Moss *et al*., 2005; Sheaves *et al*., 2007).

Despite its socioeconomic and environmental significance, the region has experienced historical conflicts between multiple, and in some cases incompatible, values and uses of coastal resources. Intensive clearing, inappropriate agricultural practices, urban and industrial development, habitat and biodiversity loss all constitute major threats to estuarine, coastal and marine linked ecosystems and species in the Burdekin Dry Tropics coastal region (e.g. Brodie *et al*., 2003; Gordon 2007; Hutchings *et al*., 2005; McCulloch *et al*., 2003; Orpin *et al.*, 1999).

This has resulted in significant increases in sediment, nutrient and chemical loads running off the land into the rivers and waters entering the GBR lagoon (e.g. Brodie *et al*. 2003; Fabricius *et al*. 2005; O'Reagain *et al.*, 2005; Wooldridge *et al.*, 2006). Seasonal floods dominated by wet summers and dry winters determine the total loads of sediments and nutrient runoff from the catchment (e.g. Devlin & Brodie 2005; Greiner et *al.*, 2005; Hutchings *et al.*, 2005). Further information about the water quality issues in the BDT region will be presented in the section describing the context of the Coastal Catchments Initiative and the Water Quality Improvement Plan.

The Stakeholders

In order to gain a rich and detailed understanding of public participation and the use of spatial information and related technology, participants of this study were identified within the scope of activities related to the Coastal Catchments Initiative (CCI) – Water Quality Improvement Plan (WQIP). Overall, participants were representative of key sectors in the region such as sugar cane farming, grazing, horticulture, science, NQ Dry Tropics NRM environmental management body, and government and non-government organisations. A brief description of key stakeholder groups is presented below. Further detail about participant selection is presented in the methodology section.

Burdekin Dry Tropics NRM (BDTNRM)

The Burdekin Dry Tropics NRM, recently renamed as the NQ Dry Tropics, is a community-based regional body established in 2002 to deliver the National Action Plan for Salinity and Water Quality, Natural Heritage Trust II and other funds. The NQ Dry Tropics Board is represented by five sub-regional groups (Burdekin-Bowen Integrated Floodplain Management Advisory Group; Townsville Natural Resources and Environment Forum; the Burdekin Rangelands Implementation Group; the Belyando-Suttor Implementation Group; Eastern Desert Uplands Sub-Region) and advised by four government members (Department of Natural Resources and Mines, the Commonwealth Government, the Aboriginal and Torres Strait Islander Commission, and the Great Barrier Reef Marine Park Authority). Its major aim is to empower the community of the Burdekin region and to deliver solutions to natural resource management issues, social, cultural and economic outcomes for the region.

Burdekin Water Quality Improvement Plan (WQIP) Steering Committee

The Burdekin WQIP Steering Committee is composed of individual members who are representative of the key stakeholder groups: grazing, horticulture, local government, sugar industry, South Burdekin Water Board, Dept. Primary Industries & Fisheries (DPI & F), Environmental Protection Agency (EPA), Department of Natural Resources & Water (NRW), Great Barrier Reef Marine Park Authority (GBRMPA), Department of Environment and Heritage (DEH), Science (Australian Centre for Tropical Freshwater), Burdekin Dry Tropics NRM (BDTNRM). The main task of the Steering Committee members is to guide the development of the Burdekin WQIP by providing advice and sharing concerns throughout the process by participating at meetings and workshops.

Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc. (BBIFMAC)
The Burdekin Bowen Floodplain Management Advisory Committee was formed by representatives of the Lower Burdekin Landcare Association in 2000 to guide development of and support the implementation of a community-driven approach to management of natural resources in the Burdekin Bowen sub-regional area. The area covered by the committee is the floodplains in the Bowen and Burdekin Shires, embracing the lower catchments of the Bogie, Don, Elliot, Burdekin and Haughton Rivers. Core functions of the Advisory committee include provision of a forum to promote discussions on regional NRM issues and facilitate cooperation and coordination of organisations and stakeholders.

Sugar related industries
Most sugar cane related industries have representatives in steering and advisory committees in the region such as WQIP and BBIFMAC. *Canegrowers Burdekin,* for instance, is an organisation which negotiates with government on water pricing, water reform and availability of water for irrigated cane farms. It also manages the implementation of water use efficiency programs for the sugar industry to increase productivity, profitability and sustainability of irrigation practices. The *Bureau of Sugar Experiment Station (BSES)*, a privately funded research provider, and the *Burdekin Productivity Services (BPS)* provide agricultural services and technical advice to growers to support a profitable, productive and sustainable sugar industry. Additionally, CSR, Australia’s leading sugar business, is a significant supplier of refined sugar products and operates the main sugar mills in the region.

Landholders
The group of landholders was mainly composed by representatives of farming and grazing industries who participated at water quality workshops and GIS-related training sessions but were not representatives of their respective sectors at organised groups or committees such as BBIFMAC and Burdekin Water Quality Steering committee.

External Consultancy providers

Consultancy providers were professionals representative of private companies contracted by non-government (e.g. Burdekin NRM Dry Tropics) and government (e.g. Department of Primary Industries and Fisheries) agencies to conduct water quality-related projects in the Burdekin region.

The Coastal Catchments Initiative and the Water Quality Improvement Plan

According the water quality plan, the aspects of water quality which are most important to the health of the natural resources in the Burdekin River catchment region are suspended sediment, nutrients, and pesticide concentrations (Brodie & Mitchel 2005; Cox *et al.*, 2005; Fabricius *et al.*, 2005). Since European settlement, inappropriate land use practices (e.g. land clearing, extensive and intensive agriculture development) in the catchment areas adjacent to the Great Barrier Reef World Heritage Area (GBRWHA) have led to increases in sediment, nutrient and chemical loads running off the land into the rivers and waters entering the GBR lagoon (e.g. Dight, 2009; Furnas & Mitchell 2001; Brodie *et al*. 2003).

Most significant contributions (87%) to the total contaminant load are attributed to grazing and sugar cane land uses and related industries (Dight, 2009). It has been estimated that elevated concentrations of diuron (3.8 mg L^{-1}) and atrazine (6.5 mg L^{-1}) herbicides in the Burdekin-Townsville region were associated with areas where sugar cane cultivation was greater than 10% of the main land use (Lewis *et al*., 2009). This situation is aggravated by pulses of freshwater discharge associated with seasonal rainfall (event flows) and rapid runoff, including suspended sediment and nutrients, into the Burdekin catchment and GBR lagoon (Devlin & Brodie, 2005).

Declining water quality because of land-based uses associated with impacts of droughts and floods are serious threats to river catchments and nearshore coral reef systems of the GBR (Hoegh-Guldberg *et al*., 2007; McCulloch *et al.*, 2003; Brodie *et al.*, 2001). There is, therefore, growing concern that downstream catchment users will have their water demands greatly affected by reduced water quality in the Burdekin Catchment (Greiner *et al*., 2007)

Recently, horticulture and grazing industries adjacent to the GBR and government programs have been developed to address water quality issues from diffuse land-based sources of pollution (Greiner *et al.,* 2009; Lewis *et al.*, 2009). Most of these Government programs to achieve environmental targets have been based on a system of direct payments to farmers and landholders through a competitive tendering processes in which farmers ‘bid’ for contracts in exchange for conservation services (Hajkowicz, 2009). In 2003, a joint initiative between the Australian and Queensland governments developed the Reef Water Quality Protection Plan (Reef Plan). The plan identified actions, mechanisms and partnerships to build on existing Government policies, industry and community initiatives to assist in reversing the decline in the quality of water entering the GBR lagoon from reef catchments (RWQPP, 2003). The development of Water Quality Improvement Plans (WQIPs) in priority GBR catchments; including the Burdekin, is identified as a core need by the Reef Plan.

In the Burdekin catchment, the WQIP aims to reduce the runoff of sediment, nutrients and pesticides from agricultural land which negatively impact on important aquatic habitats and ecosystems downstream of the Great Barrier Reef World Heritage Area (GBRWHA) coast (Dight, 2009; Greiner *et al.,* 2007). To support the development and implementation of the WQIP, the Coastal Catchments Initiative (CCI) was announced in 2002 as a new national component of the Natural Heritage Trust (NHT). The Burdekin Dry Tropics NRM (BDTNRM) organisation was contracted to prepare a WQIP for the Burdekin region (Dight, 2009). The framework for the WQIP and related CCI planning process is integrated within the scope of the BDTNRM Plan and the Regional Implementation Strategy (RIS) (Greiner *et al.,* 2007) (Fig. 4.3).

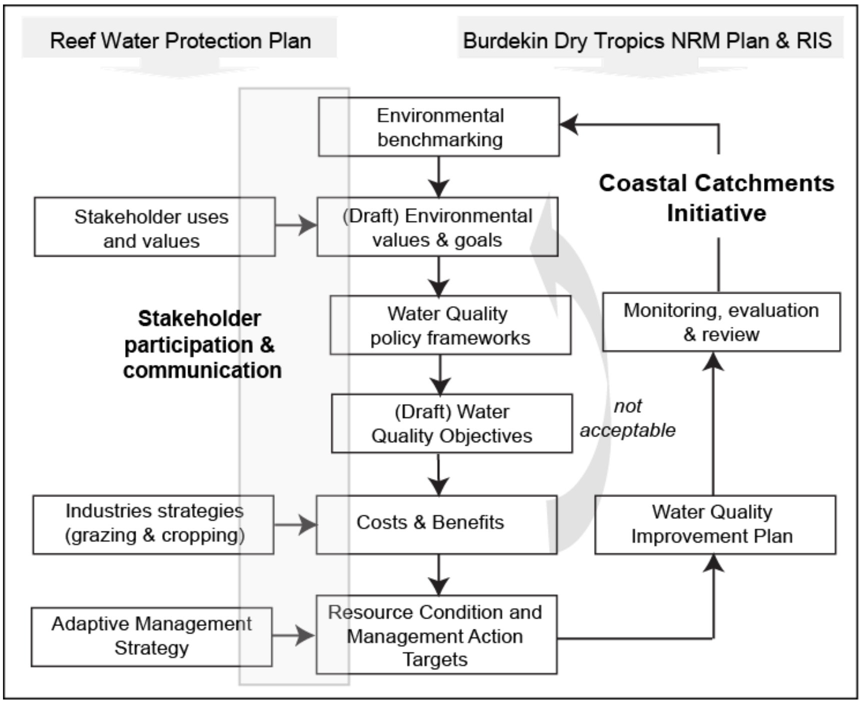

Figure 4.3. Schematic diagram of development and implementation processes of a Water Quality Improvement Plan for the Burdekin Dry Tropics NRM region. (Source: Broderick, 2007, with permission of the author).

A Steering Committee composed of representatives of the key stakeholder groups in the Burdekin catchment has been established to guide the WQIP planning process and management initiatives developed. Main initiatives implemented to achieve and to deliver significant targeted reductions in the discharge of water pollutants are addressed by the CCI (Greiner *et al.*, 2007). An example is the 'best management practice guidelines for grazing and sugar lands' and the 'environmental values and water quality objectives' initiatives. The best management practices (BMPs) aimed to provide tools and guidelines for NRM actions by landholders, industry, NRM managers and government in the Burdekin River catchment to reduce the amount of sediments and agricultural pollutants that run off farms into the Burdekin waterways (Table 4.1). Grazing land BMPs were planned to ensure a sustainable and profitable beef cattle industry by reducing the delivery of nutrients and sediments and maximising water quality (Coughlin *et al.* 2007; Coughlin *et al.* 2008). Likewise, the BMPs for sugar cane lands were focused on controlling nutrient and pesticide contamination that run off farms and affect water quality downstream on the catchment (Davis, 2006).

Table 4.1. Example of best management key issues, practices and principles for grazing and sugar cane farming for the Burdekin WQIP region. (Source: Coughlin *et al.* 2007; Coughlin *et al.* 2008; Davis, 2006; Dight 2009).

	Grazing	**Sugar cane**
Key issue	• prevent soil erosion by improving soil and vegetation cover to allow improved water filtration and absorption	• control nutrient, pesticide and sediment contamination of water leaving cane farms
Principles	• maintain land in good condition with ground cover and pasture cover that will maximise the quality of water from paddock run-off • maintain a relatively open woodland structure to maximise pasture production and ground cover, thereby minimising runoff and maintaining water quality • treat riparian lands as a unique component of the properties pasture system and managed as a sensitive area with special management requirements	• minimize excess of water leaving farms through run-off and deep drainage • reduce nitrogen and herbicide concentrations in run-off and deep drainage • reduce losses of sediment in run-off, as well as nutrients and chemicals attached to these sediments
Practices	• maintain light cattle utilization rates • manage for even utilization of pasture • use appropriate fire management • choose strategic locations of property infrastructure to avoid erosion • maintain groundcover to minimise surface flow in areas that are prone to gully and erosion • install recommended fencing and water point infrastructure to manage cattle use of, and access to, the riparian zone	• soil specific nutrient management • control traffic, permanent beds and minimum tillage • tail water recycling and storage of irrigation run off water • quantitative irrigation scheduling • holistic nutrient management planning taking into account all nutrient sources available to a crop and not just that applied as direct fertiliser • strategic and minimal use of pesticides and herbicides

The Environmental Values (EVs) and related Water Quality Objectives (WQOs) were established by the National Water Quality Management Strategy (NWQMS) and Queensland Environmental Protection (Water) Policy 1997 (EPP Water) for the development of WQIP to reduce the effects of pollution, water discharges and other land-based threats to ecosystems and waterways (Lankester & Dight, 2006). While EVs reflect the ecological, social and economic values and uses (e.g. swimming, fishing, agriculture, human consumption, visual appreciation) of the waterways, the objectives related to water quality characterise measurable indicators based on physical, chemical and biological parameters.

It is stated that the CCI and its related programs have been implemented by BDTNRM as a collaborative activity amongst various Queensland Government agencies, science providers, industry and the community (BTDNRM, 2006). It is also recognised that community involvement in all aspects of the development of the CCI-WQIP is essential to obtaining broad-based ownership of the plan and its successful implementation. To achieve that, a 'Communication and Consultation Strategy' was developed to provide a framework to effectively communicate and consult with key stakeholders in developing the water quality plan.

The complexity of management issues and diversity of participants involved in the WQIP in the Burdekin Dry Tropics region requires a better understanding of the participation mechanisms and tools necessary to meet water quality targets and to achieve pollutant reductions from land-based sources. Additionally, the projected scenario of developing more interactive spatial platforms as potential information and communication tools within the scope of the CCI provides a practical situation to analyse to what extent the application of spatial information and GIS tools can facilitate access to information and support participative processes. Although CCI has formally finished and funding has ceased in 2008, valuable lessons can be learned and guide future initiatives in the region. Information collected within the scope of the CCI-WQIP will support future development of more interactive and collaborative mechanisms for the engagement and communication strategies, particularly mapping information and geographic information tools of the BDT WQIP.

4.2 Methodological Approach

In order to achieve the study objectives, a qualitative approach was applied. The fieldwork component was designed to gather data on public participation and the use of spatial information and geographic information technologies in practical situations related to water quality management decisions. Primarily exploratory and descriptive in nature, information was collected through a combination of distinct sources including documents and reports, observations at meetings, informal conversations, semi-structured interviews and questionnaires, and an online survey and forum.

As an outsider to the country and the study region, the initial contact with the natural resource management body in the Burdekin, the NQ Dry Tropics NRM, was critical for the development of the field research. Throughout the scope of the Coastal Catchments Initiative (CCI) and water quality management activities, data were collected and participants were selected.

Sampling and Data collection

The study employed a purposeful sampling. Participants were selected in the studied area (Fig. 4.2) based on their role and involvement in natural resource management, particularly water quality-related issues, as well as their interest in public participation and the use of spatial information and tools. Both sampling and data collection were conducted until the saturation point was reached, that is, no new stakeholder group or information emerged from the studied context.

Data was collected between October 2006 and September 2007 with additional follow-up activities (mainly data validation with interviewees and participation by invitation at meetings) until June 2008. A summary of the data collection methods and sample size used in this chapter is presented in Table 4.2 followed by a detailed description of each technique.

Table 4.2. List of the data collection methods.

Method	Qti
Document Analysis (e.g. water quality reports, newsletters, meeting minutes)	80
Participant Observations	18 (77hours)
Face-to-face interviews	20
Surveys	30
hands-on [(a)]	24
online	6
On-line discussion forum	4
Focus Group	1

[(a)] 'Hands-on' is a term used in this chapter to characterise a set of self-completion questions about public participation and the use of spatial information and GIS tools provided to respondents at workshops and meetings.

Overall, this case study research adopted a strategic and flexible approach (Figure 4.4). Contextual information collected during participation at meetings and informal interviews with participants revealed that key stakeholders in that region (e.g. farmers, graziers) were reluctant to participate in more traditional forms of data collection. For instance, a common complaint was the excessive number of surveys conducted by different management agencies in the region.

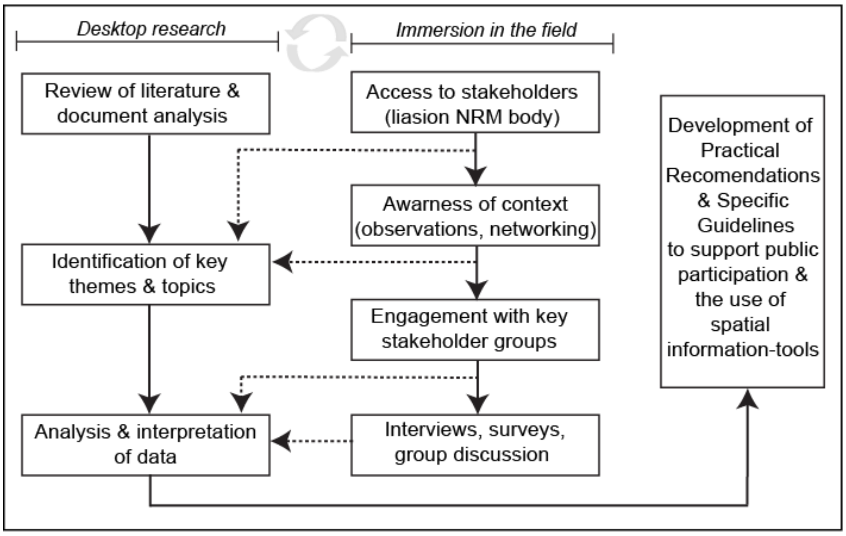

Figure 4.4 Data Collection and Analysis Framework.

In this study, the purpose of the research and the motivation of the researcher were presented at meetings (e.g. BBIFMAC and WQIP Committee meetings) and promoted by local communication sources such as the Bureau of Sugar Experiment Station (BSES) website and printed news (e.g. BBIFMAC Enviro News). In addition, a flyer for expression of interest which included a brief summary of the research and preferred form of participation (face-face, survey, telephone) was distributed. Semi-structured one-to-one interviews were then conducted with participants who expressed their interest in participating in the research. After being interviewed, if they agreed, a short structured 4-page survey ('hands-on') was provided to the participant with a pre-paid return envelope. In all cases, anonymity was assured through the application of a pseudonym in all recorded documentation. All participants were reminded that their contribution was entirely voluntary and that they could choose to withdraw at any stage. Additionally, results are reported in aggregate format so that participants will neither be identified nor related to their answers.

Review of literature and document analysis

The review of the relevant literature and document analysis was predominantly foundation research providing contextual information, guiding and supporting field research data. A systematic review of the existing information, including peer-reviewed publications, reports, meeting minutes, local magazine articles, fact sheets, newsletters, press releases, and internet resources was undertaken with the focus on the level of participation, mechanisms, opportunities and constraints of people's participation in natural resource-water quality management, as well as the use of spatial information and geographic related tools. Follow-up document analysis (mainly reports) and monitoring of online information (email newsletters, websites such as BDTNRM) was an ongoing process conducted prior to, during and after to the field research. This process allowed a continuous attachment with the context and variables under investigation. It also allowed evaluation of changes over the period of the study. A list of the documents analysed can be found in Appendix B [1].

Observation at CCI and WQIP related meetings

A total of 18 meetings and 77 hours of observation were conducted between October 2006 and September 2007 (see Appendix B for a detailed list). The meetings provided a unique opportunity to present and promote the research purpose and intended outcomes (Appendix B) and to select potential informants for interviews and short surveys. Observation at stakeholders' meetings represented an efficient way to explore issues and concepts arising from the literature review and document analysis. For instance, issues of representativeness, relations, channels of communication, interests, and inputs from the parties related to management decisions were explored. Attendance at meetings was also critical to build up trust and rapport among participants and it also greatly enhanced the quality of the interviews and follow-up activities in the later stages of the data collection phase.

[1] Appendices are in Volume 2 of this thesis.

Detailed notes taken during the meetings enabled the cross-validation of data generated from surveys and interviews. During the meetings, an informative brochure was distributed to the participants explaining the purpose and intended outcomes of the research (Appendix B). An online version of the brochure was also available. The brochure contained sections in which people could select the preferred form of participation (e.g. face-to-face interview, mail out questionnaire), provide preliminary information about their interests and issues about public participation and the use of spatial information and geographical information tools, and indicate other people who they thought might have interest in sharing ideas about such issues.

Semi-structured interviews

Interviews with key informants from the grazing and sugar farming sectors, decision makers, and experts involved in natural resource management were conducted to explore issues in-depth. A flexible protocol guide determined the main topics to be explored and subsequent specific questions emerged during the interview process. Main topics covered in the interview include: (i) current state of public participation in natural resource management in the Burdekin region, (ii) forms of public participation programs to engage people about land management practices and water quality issues, and (iii) use of spatial information and GIS tools for communication and as a decision support tool. These topics were derived from the literature, personal communication with experts, researchers and local stakeholders.

The interviews were carried out between March and September 2007 with 20 interviewees from 13 organisations involved in the management of natural resources, particularly water quality, in the region. Interviews, ranging from 30 minutes to 1 hour, were mostly conducted face-to-face at a convenient location selected by the interviewee. On just two occasions, because of distance reasons and/or unavailability of the respondent to meet face-to-face, the interviews were conducted over the telephone. The interviewee was advised that personal details were not required and that responses would be anonymous and confidential. Interviews were very interactive and the interviewer regularly checked written responses to each question to ensure that verbal responses were accurately recorded. Interviewees were encouraged to respond openly to questions and to provide examples whenever possible. All interviews were recorded and transcribed for analysis. A detailed list of institutions and sectors covered by the interviews as well as location and dates can be found in Appendix B.

Group discussion

An interactive group discussion session, held on 14th of September of 2007 in Ayr, supported the establishment and validation of themes and topics previously identified during the literature review, document analysis, observations and interviews. The event was intentionally organised to be held after the general meeting of the Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc. (BBIFMAC), so it was possible to optimise participants' time and ensure that an adequate and representative number of people participated in the group discussion. The participants were also notified that their participation was voluntary and that, although anonymity could not be assured the group was asked to respect the confidentiality of other participants, and the information provided and discussed would be reported in aggregated form.

A combination of short presentations (e.g. The Herbert Resource Information Centre (HRIC), a collaborative partnership based on a GIS facility to support decision-makers in the Herbert River Catchment) and practical activities (e.g. 'cards on the wall' in which participants explored participation levels and tools by placing and grouping cards on the wall) structured the discussion session (see Appendix B for a detailed agenda). Guided by an experienced facilitator, for over two hours, 18 participants discussed issues related to drivers for and constraints to people's participation in natural resources management (e.g. water quality monitoring, on-farm nutrient management), and current needs for spatial data and geographical information tools (Fig. 4.5).

Figure 4.5. A group of participants identifying needs, sources, benefits and constraints of spatial information. (From left to right: Graeme Porter (grazier), Reg Hugston (farmer), Maria Lange (project officer), and Stuart McCuben (landholder). Photo and names by permission of the participants - James Cook University Ethics Approval No. H2422.

Summary feedback (see Appendix B) about the main outputs of the group discussion was provided to participants one week after the event. Printed copies of the summary were sent to the next meeting of BBIFMAC, posted to those who provided mail address, and made online available at the Coastal Zone Network (http://www.coastzone.net)[3] for download.

[3]The CoastalZone.Net is a non-profit initiative created during the course of this research with the main purpose of providing a continuos space for debates, share experiences and promote collaboration in issues about integrated natural resources management, public participation and the use of spatial information and GIS tools. This project is powered by Plone, kindly maintained by the JCU's e-Research Portal Team and supported by the James Cook University.

Survey

A short questionnaire composed of 16 open-ended and closed-ended questions, about public participation and the usefulness of spatial information and GIS in water quality and land use management practices, was provided to selected participants (see Appendix B). The survey included the same topics covered by the interviews, but added more specific questions. Closed-ended responses were measured on a 5-point Likert-type scale, or by simply selecting an alternative. For instance, respondents were asked to rate their level of importance (with category 1= not important at all; 2= slightly important; 3= moderately important; 4= very important, 5= extremely important) with 17 statements about the characteristics of an effective public engagement program in natural resources management. In defining the stage of use of spatial data technologies in natural resources and land management activities, respondents were asked to select a single alternative from a number of 6 possible stages (non-existent, conceptual, infancy, growing, mature, or other).

The survey and a pre-paid stamped return envelop were provided to people who demonstrated interest in the research subject at meetings, training sessions and workshops. A reminder to return the survey was sent a week later by phone or email, and the response rate was 80%. A total of 30 surveys were returned. Of 30 surveys, only 6 were derived from the online source, despite efforts to promote it through local internet vehicles such as the BSES website (see Appendix B).

Overall, most respondents were male (68.2%) between the ages of 30 and 39 (29.4%), with a tertiary qualification/university degree (61%) or technical qualification (TAFE) (28%) as the highest educational level. The sectors most represented in the survey were environmental management body (30%), sugar cane farming (20%) and grazing (20%). The remaining 30% was represented by horticulture and non-profit organisations with 15% of each.

Data Analyses

Data analyses involved a combined qualitative-quantitative approach and triangulation of data acquired from document analysis, observation notes, interviews, surveys and group discussion. The conceptual framework, presented in the introductory chapters, and the research questions stated in the introduction were used to select, focus, and organise the data.

Qualitative data composed of document summaries, interview transcriptions and observation notes were expanded, reviewed and coded following the procedures of Grounded Theory (Glaser and Strauss, 1967) and Spectrum of Public Participation (IAP2, 2007). Data coding was performed with the qualitative analysis software QSR NVivo V.8.0.332.0 Sp4. Data were coded for themes relevant to the research questions and objectives. 'A priori-coding' phase occurred during the literature review and document analysis. This pre-analysis process of organising the data into a system of basic codes based on secondary data guided the analysis of the primary data. For example, to identify information and communication factors, strategies and mechanisms that can strengthen or inhibit public participation in natural resource management, interview transcriptions and observation notes were initially categorised as institutional scales (e.g. from national to local), socioeconomic issues (e.g. personal relationships, funding schemes) and management context (e.g. urban, rural). In a second phase, a 'post-coding' was applied in all written records to check for consistency and to organise codes in meaningful categories. In addition, quotations are used to provide evidence and illustrate themes that emerged in the analysis.

Quantitative data from the surveys were analysed using standard exploratory and descriptive statistical techniques. All statistics analysis was conducted with SPSS version 15.0 for Windows with alpha = 0.05 and Bonferroni correction ($\alpha = 0.05/n$, where 'n' is the number of comparisons). However, due to the relatively small sample size and non-random selection of the participants, robust statistic analyses were limited. Instead, results are reported as descriptive trends rather than empirical tests. Therefore, the non-parametric methods Kruskal-Wallis (to compare three or more samples) and Mann-Whitney U (to compare two independent samples) were used when relevant to illustrate trends in the data. For instance, Kruskal-Wallis was used to observe differences on the level of importance with statements about elements of an effective engagement program in natural resource management between various stakeholders groups (landholders, researchers, resource managers, and representatives of non-profit organisations). Mann-Whitney U test was performed to compare differences in opinion between landholders and resource managers.

4.3 Results

The findings presented below illustrate participation strategies and tools used to engage stakeholders in the context of the development of the Burdekin Water Quality Improvement Plan. Nevertheless, it cannot be assumed that the set of questions is exhaustive, nor that all key elements of public participation and use of spatial information and technologies in natural resource management have been highlighted. Rather, results of this chapter provide a better understanding of the contextual issues and different perceptions presented by key stakeholder groups about participation and the usefulness of spatial information in the implementation of water quality management initiatives in the studied region.

Participation in water quality management

In Queensland, government and non-government agencies responsible for natural resources management have increasingly advocated the use of public participation programs to connect with their stakeholders and engage people in land management practices and water quality issues. To assess the current stage of public participation and document the practical lessons learned by the public engaging in water quality and land management in the dry tropical coast, participants were interviewed, surveyed and observed at practical situations involved in the development of the water quality improvement plan. Overall, results reveal that people are highly motivated and committed to engage in natural resource management decisions. Survey data revealed that most respondents (88.9%, n=30) believe that government and natural resource management agencies should consult the public about issues related to water quality and land use practices.

A number of common themes, that emerged from an integrated analysis of documents, observation notes, interviews and group discussion observations, lead to the identification of core motivations, (e.g. get better services for landholders and managers), constraints and limitations (e.g. disarticulated institutional agendas, limited feedback,) about participating in water quality management decisions within the scope of the coastal catchment initiatives in the studied region (Fig. 4.6). Most of the themes identified are scattered across multiple institutional scales (from national to local), different issues (from funding to trust and relationships) and management contexts (from urban to rural).

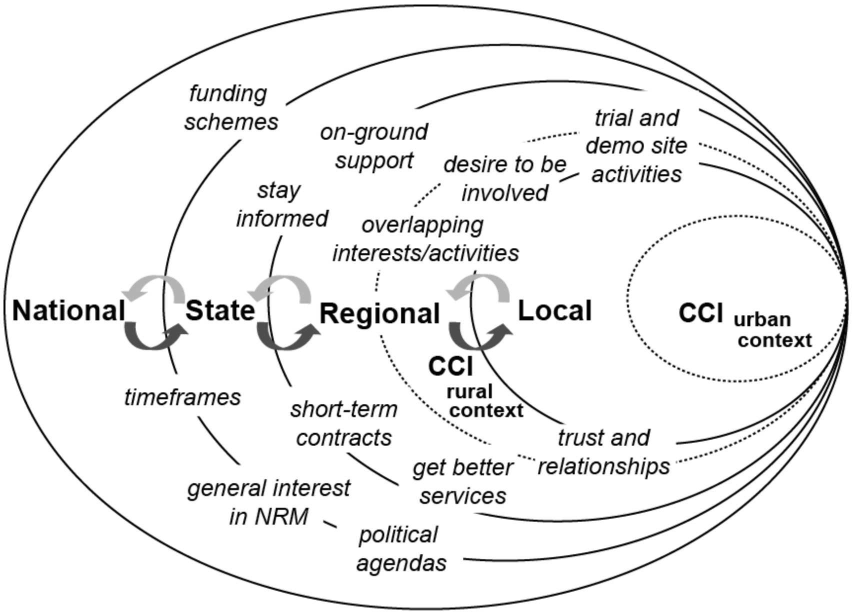

Figure 4.6. Schematic representation of major themes, institutional scales and contexts of participation in water quality management. The colour of the arrows from dark to light grey indicates the perceived strength of the relationship between the different management scales, with dark grey representing stronger influence and light weaker influence. The dashed circles represent the nested and context-dependent characteristics of the Coastal Catchment Initiative (CCI).

Motivations to participate in water quality and land management practices are mainly represented in the first three stages of the Public Participation Spectrum, including: stay informed, general interest in natural resources, get better services for landholders and managers, desire to be involved in the process and to influence decisions. For instance, some respondents stated that:

> *"I go to those meetings because I want to stay up to date with what is happening".*
>
> *"I want my concerns listened to, you can't change anything if you don't even try to communicate your concerns".*
>
> *"I desire to find out more information regarding the work of other agencies and gather relevant information".*

Others expressed motivations more related to higher levels of participation, such as involvement and empowerment, respectively:

> *"As an extension officer working in the cane industry I felt it important to be involved".*
>
> *"I want to influence the decision making process, so my opinion could be accounted".*

Attachment to the land and the environment, were also expressed by those in the farming sector, for instance:

> *"I am a farmer, I like the farm I like the bush"*.

Conversely, different constraints and limitations were identified as inhibitors of participation in water quality and land-based management processes. Disarticulated institutional agendas, mismatch between local and regional priorities at both spatial and temporal scales, and overlap of interests were commonly appointed by the respondents. Common criticisms included, but were not limited to:

> *"They've [the government] got to deliver within a certain limit of time, tremendously tight budget and timetables, and they've got to deliver and put down on paper, but not much service on the ground"*.
>
> *"A crop cycle of cane takes about five years to complete, so how can you have three years project work if you are trying to make farm systems changes, when you cannot go through one whole entire crop cycle? So it's pretty ridiculous, really"*.

In addition, limited feedback, poorly prepared staff that was often not informed enough about the entire management process, and a high degree of scepticism about the 'true' agenda of government-related meetings also restricts participation. For instance, a farmer stated that:

> *"Some meetings are merely information delivery with no real interest in changing or adjusting plans"*.

In a feedback workshop realised in Charters Towers about the about CCI Grazing Land Best Management Practices project, a grazier noted that:

> *"Many projects are just extracting and extracting from us and there is nothing back"*.

Data from open-ended interview questions also indicated that, although participation in water quality and land management issues has been influenced by on-ground actions that result in practical outcomes, significant improvement is still necessary. According to representatives of the farming sector and volunteer organisations, trial-demo site visits and volunteer activities at the property level has improved, but this is still hampered by unpredictable funding schemes and short-term contracts of extension staff. Government and industry related sectors believe that regional NRM bodies have been successful in optimising the representativeness of key sectors and stakeholders in groups and committees, such as the Burdekin WQIP Steering Committee. In addition, joint extension projects between state government and the farming sector, such as pre-clearing of vegetation and traffic control, have enhanced growers' awareness on the importance of environmental issues for the management of their properties. The provision of spatial data at 2.5m resolution by the project 'Spot 5 Satellite Imagery for Landholders', coordinated by the NQ Dry Tropics regional body, is also considered a significant step towards improved farm planning, participation in water quality management and promotion of sustainable natural resource management throughout the region.

To better assess stakeholders' views and understanding of the public participation process, survey respondents were asked to choose among a set of five definitions, ranging from inform to empower stages of public participation, which alternative would best define an effective communication and engagement process. It is important to state though that, to not influence respondents' choice, just the descriptive statements were provided in the survey and not the participation categories (e.g. inform, involvement). The majority of respondents (53.3%) believe that an effective communication and engagement process in natural resources and land-based management processes should INFORM, LISTEN, ACKNOWLEDGE people's concerns and provide FEEDBACK on how their input influences decisions (Fig. 4.7).

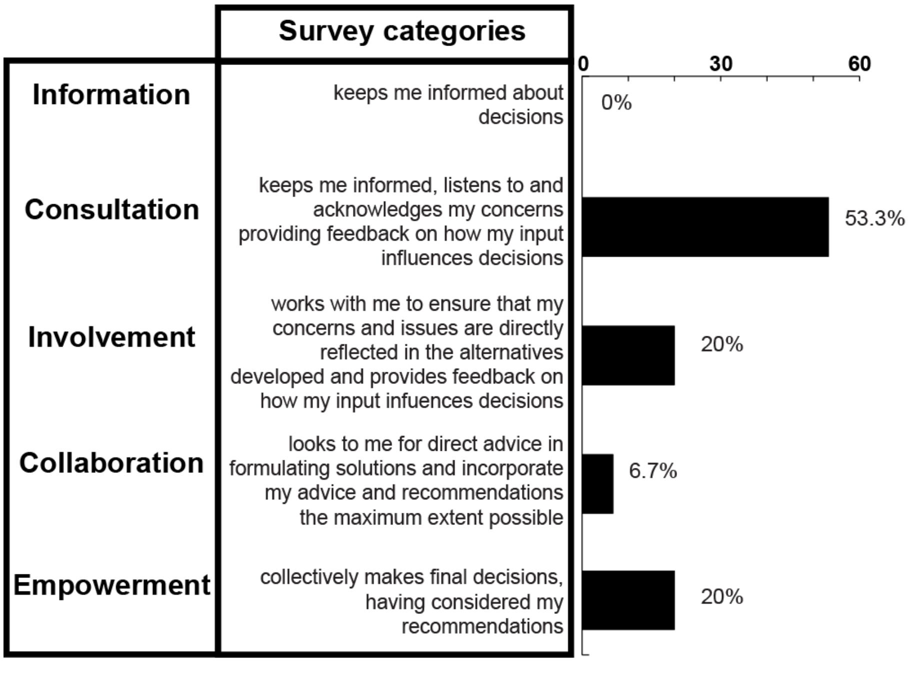

Figure 4.7. Identification of an effective communication and engagement process in natural resource and land-based management issues. Categories and statements were based on the Spectrum of Public Participation (IAP2. 2007)

However, information presented in Figure 4.7 might be biased by people's interpretations of the different levels and techniques of participation. For instance, results from a group discussion activity conducted with 18 participants from different sectors (e.g. farming, grazing, government and non-government organisations) shows some degree of misinterpretation of levels and related techniques of public participation. Therefore, to better comprehend participants’ understanding and perceptions of public participation process within the context in which the case study was investigated, a group activity was conducted with the participants. Participants were provided with different examples of public participation activities (e.g. fact sheets, workshops, advisory committees) and asked to place the examples at the level (inform, consult, involve, collaborate, and empower) where they believed most activity has taken place (Fig. 4.8).

a) b)

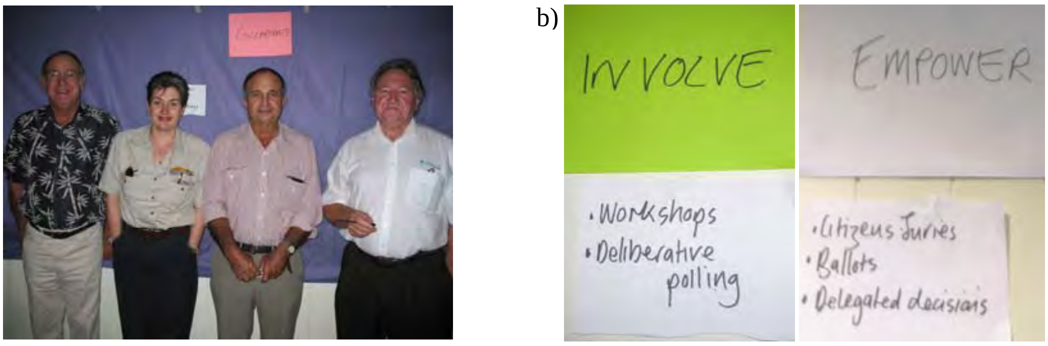

Figure 4.8. Interactive group discussion activity. a) A group of participants in an interactive activity about sharing understanding of the different levels and techniques used in public participation. (From left to right: Graeme Porter (grazier), Sarah Connor (BDTNRM), Ray Menkens (landholder), and Bob Osborne (Greening Australia). b) Detail of wall cards of different levels of public participations and associated techniques placed by participants. Photo and names by permission of the participants - James Cook University Ethics Approval No. H2422.

After participants reached a consensus and agreed on the position in the spectrum according to the examples of the tools provided to them, the facilitator explained which groups matched the participation level with its respective tools. Overall, the group that had the techniques 'public comment, focus groups, surveys, public meetings' misplaced it under COLLABORATE instead of CONSULT, and the group with 'citizen advisory committees, consensus-building, participatory decision-making' techniques misplace it under EMPOWER instead of COLLABORATE. The groups with the INFORM (‘fact sheets, web sites, open houses’) and INVOLVE (‘workshops, deliberative polling’) techniques placed it under the corresponding level of participation. This exercise showed, for instance, that when participants believed they were collaborating (which represents a higher level of participation) they were in practice being consulted. Misinterpretation or different interpretations of levels and related techniques of public participation might result in false expectations of how people’s contribution has been sought and, consequently, dissatisfaction with the process and even the outcomes. This might affect not only the relationship between stakeholders and the management agency, but also the way people provide information and engage in the process.

Additionally, perceptions of public participation processes were measured by asking survey participants to rate the level of importance (with categories 1 = not at all important; 2= slightly imporant; 3= moderately imporant; 4= very important; 5= extremely important) for 17 statements about possible outcomes and attributes of an effective engagement program in natural resource management (Table 4.3). Respondents tended to rate as very or extremely important that an effective engagement program would:

i) 'result in the best outcome for the natural resources';
ii) 'result in an outcome that is fair to all affected groups' and 'not cost people too much money to participate';
iii) 'allow citizens to express their opinions to resource managers', 'give people a genuine opportunity to influence decisions', and 'result in the best outcome for landholders';
iv) 'improve the relationship between managers and citizens' and 'allow local concerns to be incorporated into decisions'.

Overall, survey respondents perceived an effective engagement in natural resource management as a process in which environmental, social, economic and political domains are considered (Table 4.3). Regardless of distinct perceptions (e.g. government and industry related sectors believe that regional NRM bodies have been successful in optimising the representativeness of key sectors and stakeholders, while landholders' representatives consider that most committees formed have similar members and lack of on-ground representatives) no distinct trend ($p > 0.05$ for all statements) was found between the key sector groups (landholders, researchers, resource managers, and representatives of non-profit organisations) and their average value of the level of importance of elements of an effective engagement program. Most respondents agreed that an effective engagement process should result in best outcome for the natural resources (environmental domain), but also should be fair to all affected groups (social and political domains). In addition, an effective engagement process should not cost people too much money (economic domain). Nearly all statements rated as not or slightly important were related to benefit the group with the most at stake (political domain), costs to the government (economic and political domains), and time necessary to participate (social and economic domain) in the process.

Table 4.3. Level of importance with statements about elements of an effective engagement program in natural resource management (N=30).

	Level of Importance (% of respondents)				
Elements of an effective engagement program [(a)]	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Follow a process that is easily understood by everyone	0	0	11	33	56
Result in an outcome that is fair to all affected groups	0	0	12	32	56
Give people a genuine opportunity to influence decisions	0	0	17	28	55
Improve the relationship between managers and citizens	0	5	17	28	50
Allow local concerns to be incorporated into decisions	0	0	6	50	44
Give all equal opportunity for all citizens to participate	0	6	11	39	44
Involve the public at all stages of planning	0	11	22	28	39
Result in the best outcome for the natural resources	0	6	0	72	22
Do not cost people too much money to participate	5	11	6	56	22
Allow citizens to express their opinions to resource managers	0	0	17	55	28
Result in the best outcome for landholders	0	6	17	55	22
Do not allow any group to have too much influence in decisions	5	5	5	45	40
Allow resource managers to express their opinions to citizens	6	0	33	44	17
Do not require too much time for people to participate	16	6	44	28	4
Do not delay the implementation of important management changes	6	17	47	12	18
Do not cost the government too much money	17	22	56	5	0
Favour the group with the most at stake	22	28	33	11	6

[(a)] Cronbcha's α =0.80 indicates an acceptable level of internal consistency reliability.

Colour Scale									
Percentage	0	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80

Mean ranks[4] of the Mann-Whitney U test, performed between landholders and resource managers, found that the two groups more represented in the survey with 42% and 36% of the answers respectively, suggest that distinct trends in perception of an effective engagement process do exist between landholders and resources managers. Landholders presented higher Mann-Whitney mean ranks to elements related to the engagement process ('Follow a process that is easily understood by everyone', mean rank= 7.50), the time related to the implementation of management changes ('Do not delay the implementation of important management changes', mean rank= 7.44), the expression of opinion by citizens ('Allow citizens to express their opinions to resource managers', mean rank= 7.13), and outcome ('Result in the best outcome for landholders', mean rank= 6.88). For resource managers, statements related to power ('Favour the group with the most at stake', mean rank= 8.13), cost ('Do not cost people too much money to participate', mean rank= 8.00), time ('Do not require too much time for people to participate', mean rank= 7.88) and relationships ('Improve the relationship between managers and citizens', mean rank= 7.00) appeared more relevant.

Data from interviews suggest that, in practice, participant and level of importance towards an effective engagement program within the context of the water quality management is related to linkages and interactions among three major spheres composed of the interested public, the regulator agency, and the operational facility (Fig. 4.9).

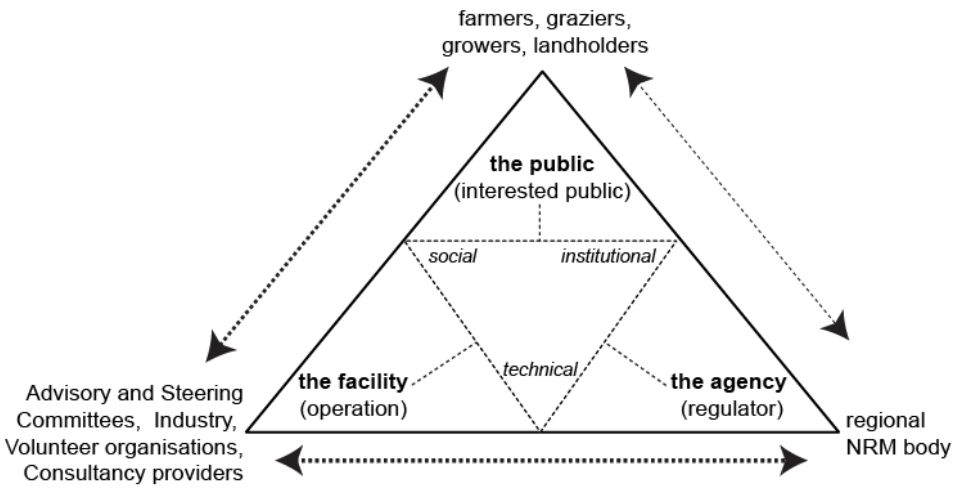

Figure 4.9. Alliance triad between the public, the management agency, and the operational facility. The thickness of the arrows indicates the level of perceived relationship strength and interaction between the three components. (Source: Adapted from the RCRA Public Participation Manual, EPA 1996).

[4] Mean ranks represent the mean rank score for each group. It is a measure equivalent to the mean used by the Mann-Whitney U test for ordinal data. The test takes all the cases from the lowest to the highest score and computes the mean of the ranks in each group.

The triad of engagement highlights the critical role of the interested public (farmers, graziers, growers, landholders), the regulator (NRM body), and the facilitators (advisory and steering committees, volunteer organisations, and external consultants) in establishing and maintaining a two-way interactive process. However, data from interviews and observation at stakeholder meetings indicate that, in practice, the level of strength of relationships between the three components is dissimilar. Stronger interactions were observed between the NQ Dry Tropics NRM (the regulator agency) and operational facilitators, such as sugar related industries (e.g. BSES, BPS), natural resource committees (e.g. BBIFMAC, WQIP committee), and volunteer organisations (e.g. CVA, Greening Australia). Natural resource management agencies are increasingly relying on the support of volunteer organisations and external private consultants as executors of extension services. In this regard, a respondent commented:

> *"Bodies such as regional NRM and city councils work and fund some volunteer organisation projects because they have access to volunteers and a good network with a range of community members".*

Other respondent added:

> *"People don't want to do volunteer work for the councils because they believe they already pay the taxes for what the council has the obligation to do".*

Consequently, while the relationship between NQ Dry Tropics NRM (the regulator agency) and operational facilitators (e.g. BSES, BPS, BBIFMAC, WQIP committee, CVA, Greening Australia), and between the operational facilitators and the interested public (landholders, farmers, graziers) is strengthened, the relationship between the regulator agency and the public is weakened. Although NRM bodies, such as the NQ Dry Tropics NRM, report that the number of projects on the ground, communication and engagement officers, and extension staff has increased in the last years, such effort is still hampered by instability of staff and limited timeframes. As noted by a respondent:

> *"... Staff shifting and short timeframes are still the biggest problems for a stable relationship and ongoing communication process with the community".*

As presented in the Figure 4.6, differences in institutional scales, funding schemes, and incongruent timelines are major impediments towards participation in water quality management. Relationships, networks, and an effective communication process play a vital role in engaging people in management-related practices. As observed by a respondent from a volunteer organisation:

“Connections are made 'with individuals inside the organisations and not with the organisation itself. It is personality driven instead of institutional driven”.

Therefore, effective information and communication strategies are critical tools for improved public engagement programs in natural resource management in the studied region. Each corner of the alliance triangle (Fig. 4.9) supports essential linkages that need to be strengthened and functional between any two groups if public participation is to be a realistic goal.

Information and communication mechanisms, strategies and tools

The previous section highlights key motivations, constraints and limitations of participation in water quality and related land-based management processes. In spite of people’s willingness to participate and reported efforts by management agencies of improved communication and consultation processes, an effective information and communication strategy and ongoing linkages between landholders and management officers were found to be critical issues for enhanced public engagement in natural resource management.

To support the development of more effective communication and engagement plans and activities, the different information and communication strategies and mechanisms used within the scope of the of the CCI- WQIP Communication and Consultation were investigated (Table 4.4). Additionally, people’s understanding of the usefulness of some of the most commonly used techniques for engagement in natural resources management were assessed.

Documented analysis of reports and online news sources (e.g. Country to Coast News, formerly Burdekin Bites, BBIFMAC EnviroNews), within the scope of the WQIP, reveals that most of the engagement mechanisms and strategies under development or proposed were related to the first three levels of public participation (inform, consult, and involve). For instance, the main instrument designed to provide a framework to coordinate and support the communication and consultation elements of the WQIP and related activities, the CCI Community Engagement and Communications Strategy (BDTNRM, 2006), and most of the online information monitored showed tools and engagement techniques at the initial levels of participation (Table 4.4).

Table 4.4. Summary of information, communication and engagement tools and techniques within the scope of CCI-WQIP and related activities.

	CCI Community Communication and Consultation Strategy*			**Information / monitoring**
Direction	Level of Engagement	Milestones/Actions	Techniques and Communication tools	Examples
↓	Inform	• web site portal developed, develop communication materials	• media releases, newsletters, radio interviews, forums, public meetings, posters, pamphlets, fact sheets, maps/reports on website, send reports copy to stakeholder groups, roadshow, on-farm visits	• webportal (e.g. NQ NRM, CoastInfo), expo and forums, showcases, workshops, farm demonstration trials, newsletters, internet shed meetings
↑ ↓	Consult	• engage with identified stakeholders for input, develop draft report/map of environmental values using icons	• meetings/workshops, surveys, map/report on website for feedback, sent map/report to stakeholder groups, roadshow, on-farm visits	• community input – NQ NRM website, surveys, telephone interviews, roadshows, internet shed meetings
↓↑	Involve	• selection and presentation of targeted subset of WQBMP's for discussion at CCI roadshow	• oral presentation, briefs/workshops to stakeholder meetings to elicit feedback	• farm walk (e.g. Alternative Irrigation Project), field days, tender incentives, grants, training workshops, monitoring activities
↓↑	Collaborate	• dissemination of draft sugarlands WQBMP's to grower WQ focus group for feedback	• regular meetings, emails, phone calls, employment project officers, electronic distribution, discussions with steering committee, personal follow-up	• steering committees, project officers
↕	Empower	• DEH and steering committee endorsement draft	• email DEH	-

*Note: Adapted from CCI Community Engagement and Communications Strategy. Original document provided in excel spreadsheet format by the acting Community & Engagement Manager 11/01/2007.

To investigate how stakeholders feel about the public participation processes, survey respondents were asked to rate the usefulness of some of the most commonly used techniques for engagement in natural resources management. Advisory committees (65%), agency branch offices in local communities (62%) and media releases (58%) were the highest ranked techniques (Fig. 4.10). The lowest level of use was attributed to volunteer activities (33%), followed by written submissions to natural resource management bodies, public hearings and surveys with 17% of the responses each.

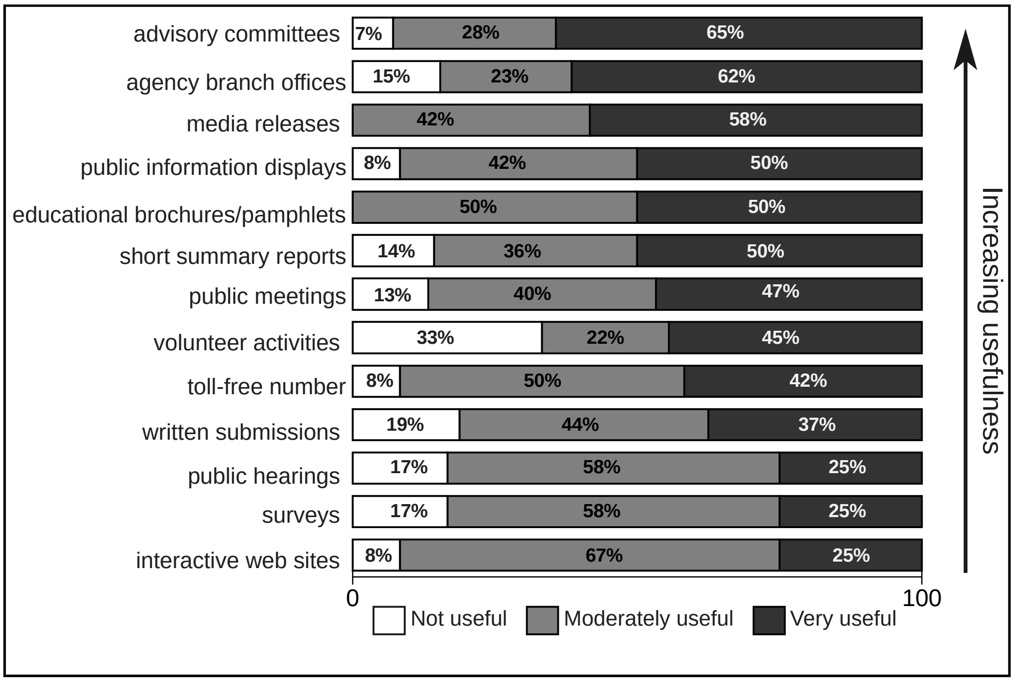

Figure 4.10. Perceptions about the usefulness of various techniques for consulting the public about natural resource management.

Data from open-ended interview questions suggest that, in spite of its utility as an engagement technique, the increased number of committees formed in recent years is excessive. As noted by a grazier:

> *"They [government] put 45 different groups in the Burdekin area. One group working with soil issues, another one working with water, and so on. It is just too much people".*

In this respect, a respondent from a government institution also added:

> *"From a regional perspective we serve the six regional bodies up here. It is an enormous time commitment, but what is problematic for me is that there is possibly more meetings and committees than is actually required. Lots of time and effort goes into that coordination, integration, etc.".*

The issue of representativeness with the same people integrating different committees was also questioned during the interviews and observed meetings. As a respondent observed:

> *"Nobody is interested in setting up other committees if the core people are the same over and over again. Nobody pays me to go to meetings! We need on-ground people".*

In spite of the low level of volunteer organisations reported in the surveys, data from open-ended interview questions reveal that volunteer organisations are still considered a valuable technique for community engagement in natural resource management. Most volunteer communication mechanisms rely on mailing-lists, the CreekWatch website, newspapers, flyers, display events, display posters, and reports. In addition, according to a representative from a volunteer organisation:

> *"The word-of-mouth is still the best communication tool. It is better to get one person involved by using the word-of-mouth process than investing with mail-outs and have no answer at all, which is usually what happens"*.

In this regard, a respondent from the Burdekin NRM body also commented:

> *"We have used hand-out surveys at markets, mail-out surveys workshops and other events, but I think the face-to-face communication is still the most successful method to consult the community"*.

To better understand the usefulness of information, communication and engagement techniques in practice, participants of an interactive group discussion composed of different stakeholder groups of the studied region were asked to reach a consensus on examples of best and/or potential communication and engagement practices in land and water management in the Burdekin WQIP region. It also aimed to develop participants' understanding of how such practices could be applied in their fields. The result of this activity is presented in Table 4.5. It identifies specific topics and thematic groups of information, communication, and engagement activities based on 'on-ground' experience, multiple engagement strategies, and applied outcomes.

Table 4.5. Best communication and engagement practices in land and water management in the Burdekin WQIP region identified by participants.*

Thematic Groups	Topics
Defined strategies and directions from government and regulatory bodies	• Gazetted government recognised area (e.g. North and South Water bodies) • Lead agency addressing specific issue • Why only Ministerial decisions? • Communication strategy • Mechanisms where a decision can be made
Effective and relevant training and workshops	• Come, See and Do workshops • Training/workshops (e.g. land-water management plans) • Effective workshop Process-Outcome NOT pre-determined
Representative local-based participation and ownership	• Captive audience-existing groups (community, schools, industry) • Local groups: land managers and technical support • Personal involvement (e.g. productivity boards, BSES, BBIFMAC)
Practical on-ground experience	• Trials and demo sites • Field days and walks
Public forum dinner and invited speaker WEB on Wednesday teleconference and internet questions-answers	No specific topics identified

* Identified by 18 participants, including farmers, graziers, non-government organisations (e.g. BDTNRM, Greening Australia, BBIFMAC, Canegrowers) and government organisations (e.g. DPI) and independent consultants, of the group discussion held on Ayr on 14th September 2007.

Observation data acquired from stakeholders' meetings supports the information presented in Table 4.5. It shows, for instance, that an effective workshop process with no predetermined outcomes is really important for communicating and engaging people in land and water management practices. Perceptions of pre-determined outcomes might affect not only the relationship with the management agency but also the way people provide information and engage in the process. As expressed by a stakeholder during a mapping consultation exercise for the WQIP-environmental values project:

"Is it the fishing zones? What you mean by put on the map? Is it just for the managers? We are still concerned about the rezoning of GBR and so about some feedback in the freshwater too".

Furthermore, on-ground experience with practical property demonstrations and best practice case studies were reported as valuable techniques in communicating and engaging landholders in land and water management in the Burdekin. Comments of some participants captured at meetings and workshops are illustrative of this point:

"Public recognition and care of people who really have good intent is important because there is lots of negative press [media] about our business".

"Yes, they are using aerial photos of the Great Barrier Reef showing runoff coming from land activities".

"See other people's ideas it's really good. People in this game like to hear about people in the same game". We need to identify and have a mutual contact with them".

Many information, communication tools and mechanisms have been developed under the umbrella of broad programs (e.g. Environmental Values (EVs) and Water Quality Objectives (WQOs), established by the National Water Quality Management Strategy) and they are not tailored to specific contexts and stakeholders' needs. Mapping data and geographic information tools have been increasingly used to facilitate information flow and to foster communication in land-use planning and natural resource management. The next section of the results addresses this issue by analysing the extent to which spatial information and geographic information tools are used to facilitate access to information and to support communication within the context of the WQIP.

Use of mapping information and geospatial tools

Spatial information and geographic information tools were prominent in use by the WQIP for the collection of data, to facilitate access to information, and to support communication on land-use planning and water quality management activities (Fig. 4.11).

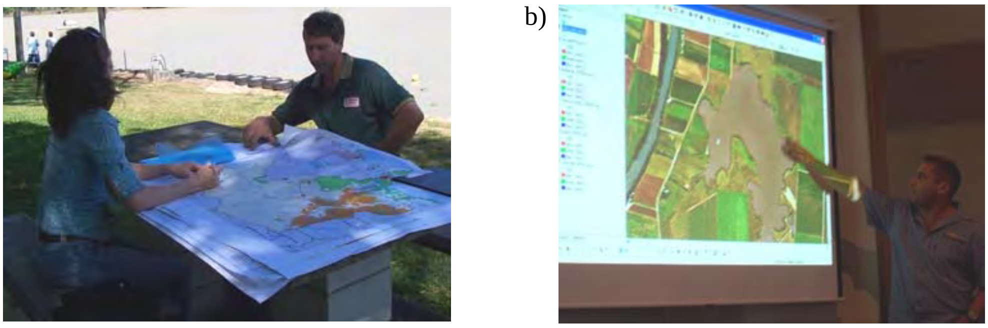

Figure 4.11. Use of mapping and satellite imagery information within the scope of water quality and land-based management projects coordinated by the NQ Dry Tropics Land and Water Solutions. a) Mapping exercise consultation as part of the Environmental Values Project. (From left to right: Ally Lankester, ACTFR-JCU, and Jamie Vacher, Lower Burdekin Ski Club), and b) GIS and Information Manager, Doug Willis from the NQ Dry Tropics, in a presentation about the Spot5 Satellite Imagery Acquisition Project. Photo and names by permission of the participants - James Cook University Ethics Approval No. H2422.

In addition, the NQ Dry Tropics has also used mapping information to consult the public and get feedback about the 'The Draft Water Quality Improvement Plan'. The Burdekin WQIP (BWQIP) Catchment Atlas[5] (accessible via web, CD or PDF downloadable) provides maps of the 6 basins and 48 subcatchments linked to summary articles of resources condition for the BWQIP region. Overall, during the period of data collection for this research and within the scope of the WQIP, the management resource agency has mainly used spatial information either as a source of providing information or collecting information from its stakeholders.

GIS-based and satellite imagery training workshops, such as the one illustrated by Figure 4.11b, are more interactive since they provided the opportunity for two-way communication between the trainers and participants. However, despite the growing demand and the high interest of landholders, this initiative was restricted by lack of trained staff (only two GIS officers), available funding and long travel distances. As observed by a grazier in a feedback workshop about 'CCI Grazing land best management practices':

> *"My husband put everything [fence, cattle numbers, and grass cover] in the GIS Farm Map software. We also got the Phoenix software provided by the Burdekin Dry Tropics NRM, but we are not using it because there is not technical support after the training*

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[5] The BWQIP Catchment Atlas is available at http://www.bdtnrm.org.au/bwqip/atlas/. Last accessed: 13/06/2009.

> *workshops. I think a series of regular on-property workshops would be a great follow-up".*

In this context, the support of operational facilitators such as AgForward[6] and Greening Australia[7] seemed to be critical in assisting producers and landholders with GPS training, computer mapping support, and provision of spatial imagery for land-use and vegetation management.

To provide a better understanding of the application status of spatial data and related technologies, survey respondents were asked to select among five alternatives which one represented the stage of use of spatial data and related technologies in the course of their activities: *Non-existent* (never or have plans to use it), *Conceptual* (just talking at this point, but it has not been implemented), *Infancy* (software is provided and its use has just started), *Growing* (a bit of GIS has been done and needs are growing), and *Mature* (data and technology are integrated into activities). Overall, survey results indicate that the level of use of different types of maps and geospatial/mapping tools was generally moderate and that the use of spatial data technologies in natural resources-land management activities is still limited, but growing (40% respondents) (Fig. 4.12). From those 40% who reported that the use of maps and geospatial/mapping tools is growing, the majority (57%) represented NRM bodies. Representatives of NRM bodies were also the majority (52%) who believed that the use of spatial data and related technologies was in a mature stage of use. For most sugar cane farming and grazing, the use of such information and tools was still either at the conceptual (28.6% and 50%, respectively) or the infancy (28.6% each sector) stages of use.

[6] AgForward is an initiative of AgForce Queensland initially established with funding from the Queensland Government to help primary producers and landholders interpret the *Vegetation Management Act 1999*. Further information can be found at http://www.agforward.org.au/index.htm. Last accessed: 13/06/2009.
[7] Greening Australia is a community based organisation that provides vegetation and environmental services to all levels of government, industry, the private sector, and community. Further information can be found at http://www.greeningaustralia.org.au/. Last accessed: 13/06/2009.

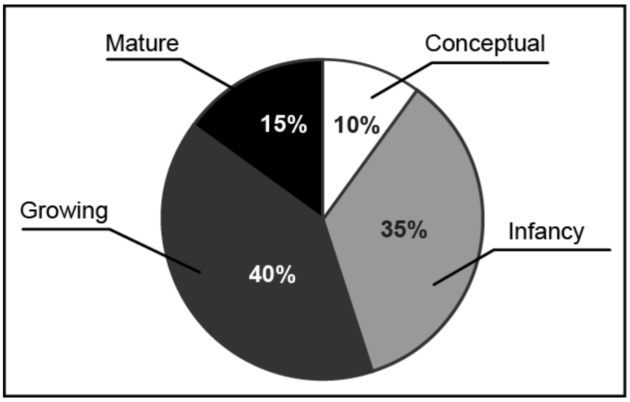

Figure 4.12. Stage of use of spatial data technologies (e.g. satellite imagery, geographic information systems) in natural resources-land management activities. (n=30).

The level of usefulness of specific mapping, spatial data and geographic information systems was analysed in an attempt to understand how people in the studied region perceive and use such tools in the course of their activities. Survey respondents were asked to rate (with categories 1 = not at all useful, 2= moderately useful, 3= very useful) their level of use with 7 common mapping and geographic-related tools. The highest level of use attributed to 'Paper maps and/or land use charts' (45%) and 'Aerial photographs' (22%) (Fig. 4.13). Respondents were less likely to find useful 'GPS photolink' (56%) and 'satellite imagery (22%). Analysis of interview and observation data reveals that reasons for the lowest rank of such tools were mainly related to: (i) uncertainty about data sources, (ii) availability of relevant data (including scalability), and (iii) lack of technical skills and spatial expertise.

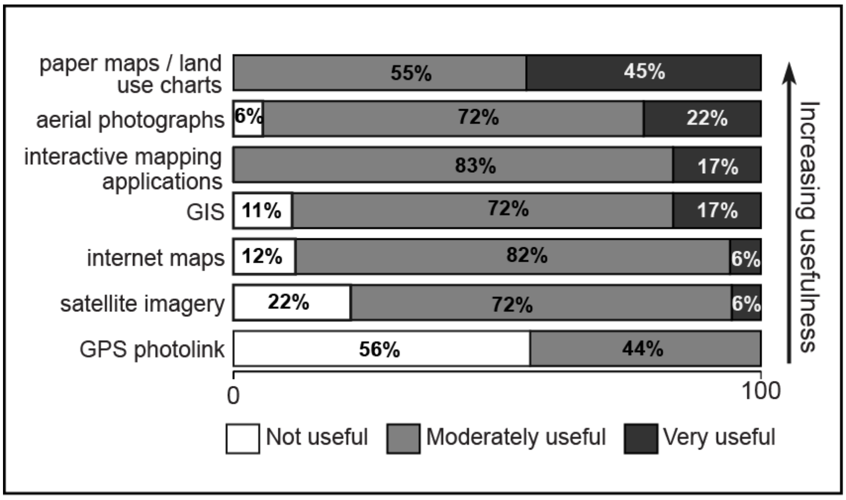

Figure 4.13. Use of spatial data and related technologies in natural land-based management activities.

The comments of representatives from community based organisations are illustrative of the reasons for the high level of use attributed to paper maps and aerial photos:

> *"Although many farmers have computer capacity and satellite dishes, people still prefer the old paper maps. It is hard to them to send the data out, mainly because computer capacity for data transmission, and farmers' lack of skills".*
>
> *"Farmers want to focus in little things inside their properties, so the exposure to aerial photography allows them to see the big picture, better than the old satellite image and even the Spot5 imagery. They need spatial information [maps] mainly to identify erosion spots and to fix it. They don't want their soil to go away. They also need the spatial information to ask for permits to clean weeds and to renew leases".*

Interview results show that, although landholders are implementing high precision yield monitoring technology and GIS to improve their crop production, most of them attributed their use of mapping and spatial information to satisfy government requirements for applying for permission to manage their property. As a farmer observed:

> "*With GPS now we all use mapping of some sort, for cattle, fences or road, everything is on a map. But for most we still use the old methods. If you want to develop, clear some country or put a water dam in the farm, you need to get a license. So we need maps to put an application and get the permission to do it".*

Conversely, reasons for the low usefulness of geographic information technology were mainly related to lack of technical skills and spatial expertise. As noted by a community organisation respondent:

> *"We don't use mapping and GIS as much as we could. We could use more maps to show sampling site locations, but lack of knowledge is the main constraint why we don't use GIS. We have used Google Earth images sometimes in community events, but it doesn't have enough detail to show local places".*

Mismatch of scales between the data available and the data needed is another reason for the moderate level of use attributed to satellite imagery. In this regard, a respondent from the cane growers sector commented:

> *"Satellite images such as Landsat and Spot just can be applied to large properties, but small properties [200km^2] need more detailed information which is not currently provided by resolution of Landsat and Spot. So, tools such as Google Earth are used just for curiosity, but they are not useful".*

About the use of satellite imagery, another participant added:

> *"I printed a Landsat satellite image of 1995 and displayed it at a wall at home, but I could not quite understand the image because of the colours. It was a sort of brown, it would be better if the vegetation was in green".*

Specific requirements of stakeholders were assessed during a group discussion activity in which participants were asked to identify their major needs, priorities, sources of information, benefits and constraints for spatial information and related technologies in land and water management in the Burdekin WQIP region. Results indicate that landholders' main interest in spatial information and GIS include, but are not limited to: (i) recording information at the property scale, (ii) project mapping, (iii) documenting on-ground work, and (iv) pre-plan land management activities (Table 4.6). However lack of skills, difficulties accessing information, inadequate spatial scales, tight timelines, government funding schemes, and instability of NRM personal were identified as the main constraints to a participatory use of geo-information technology. As a group discussion participant expressed:

> *"It is necessary to get an understanding of what is technical and what someone can do. There is lots of technical knowledge, but no practical experience. Much of what [spatial data and GIS software] is available it is not related to the circumstances of what we are doing. Technical things don't go on the ground."*

An additional constraint found during face-to-face interviews was the lack of trust with mapping and spatial data provided by government organisations. Most landholders believe that such data is inaccurate and does not reflect the real conditions of their properties. As some graziers noted:

> *"If you go the farming planning side there is the government data, but we obviously use private ones if we need them. The government has this vegetation management on map that is inaccurate, we do not believe it. Most of the vegetation is located wrong, and it also shows the wrong type of vegetation. So they [government] use bad information to make the maps".*
>
> *"My husband and I have bought aerial photos from 1995 and 1999 to show vegetation thickness on our property for a government requirement. But government's interpretation of vegetation thickness was completely different of our understanding; it did not match our reality".*

A GIS private consultant stated that the lack of ground truth points and the various interpolations necessary to produce the final product are the major problems for the lack of accuracy in government spatial datasets.

Table 4.6. Major needs, priority, main sources of information, benefits and constraints for spatial information in land and water management in the Burdekin Dry Tropics NRM region. *

Needs	Priority	Sources	Benefits	Constraints
• tree density • location of weeds • soil mapping contours	high high high	EPA, DNW, BDTNRM, GA	• priority management plan • applications for funding and clearance • location of infrastructure	• satellite imagery poor quality • capacity of internet access • skills of operator • lack ground points
• central access portal	high	Council, BDTBNRM, BSES, CSR	• easy access (single point)	• fragmented sources
• cadastral hydrology • (e.g. groundwater levels, pH) • soil types • crop type • soil carbon bores • historic data development	high high high high medium	Council, EPA, CSIRO, BDTNRM	• land capability • improved agriculture • reduced environmental impact • aid to decision making	• layering info • data ownership (privacy) • mapping data at too coarse scale • lack of accessibility
• registered plan boundaries 1:2500 • paddock boundaries 1:2500 • water courses 1:2500 • state owned roads 1:2500	high medium medium low	BSC, CSR, CSIRO, JCU, DRW, DEH, Geoscience Australia, DPI&F, EPA, North BWB, South BWB	• provide maps to the harvester, contractor, fertiliser • safety - showing powerlines, water coursed, neighbouring, crops • strategic planning	• costs • unawares of information sources

* Identified by 18 participants, including farmers, graziers, non-government organisations (e.g. BDTNRM, Greening Australia, BBIFMAC, Canegrowers) and government organisations (e.g. DPI) and independent consultants, of the group discussion held on Ayr on 14th September 2007.

To analyse the overall extent to which spatial information and geographic information tools can be used to facilitate access to information and to support communication, survey respondents were to rate their level of agreement with eight statements about use of mapping and geospatial technologies to facilitate stakeholders' participation in natural resource planning and management processes (Table 4.7). The majority of respondents believe that 'GIS and satellite imagery create new opportunities for participation in decision-making processes' (71%) and that 'Mapped information increases people's awareness of issues about natural resource management' (65%). They also identified that lack of skilled staff (70%) and software affordability (47%) are major constraints for the use of geospatial information tools to facilitate participation in natural resource planning and management processes.

Table 4.7. Level of agreement with statements about the use of mapping and geospatial technologies to facilitate participation in natural resource planning and management processes.

	Level of Agreement (% of respondents)				
Statements about use of mapping and geospatial technologies [(a)]	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Spatial information and mapping tools help environmental managers translate and better understand natural resource management issues	0	0	18	41	41
Geographic information systems are too complex to be used by non-trained users	6	0	19	44	31
GIS and satellite imagery create new opportunities for participation in decision-making processes	0	0	12	71	17
Lack of skilled staff is a constraint for the use of geospatial tools	12	0	0	70	18
Mapped information increase people's awareness of issues about natural resource management	0	0	18	65	17
Infrastructure and data accessibility are major problems	6	12	29	35	18
Online mapping tools maximise opportunity for engagement in natural resource issues	0	8	50	25	17
Software costs are affordable	12	35	35	12	6

[(a)] Cronbcha's α =0.70 indicates an acceptable level of internal consistency reliability.

Colour Scale									
Percentage	0	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80

A comment from a cane farmer and cattle property respondent is illustrative of the use of mapping information and GIS for property management and participation in natural resource planning:

> *"There is no doubt it [mapping and computers] helps people to make better informed decisions. Government requests maps from us all the time to be put in the plans. But if you've got to register the parcel of land and the available maps are not that good or accurate or old, or something the technology is not put into much of a friendly type, then it is not useful for us".*

Document analysis and observation data also suggest that mapping information creates opportunities for participation and raises people's awareness of natural resource management issues. The provision of maps and use of spatial information has increasingly been requested as essential components for the application and assessment of projects for government funding schemes such as the Envirofund[8]. Such schemes provide grants as a way to promote involvement of community groups in developing on-ground environmental activities (e.g. replanting, fencing, weeding) and to support the sustainable management of natural resources.

Overall, results show that the role of spatial information and geographic information tools in facilitating access to information and supporting communication in land and water management processes has increased. During the course of the data collection phase for this research, various examples, not necessarily linked to the WQIP were also identified. For instance, the 'Pastures from Space'[9] website, coordinated by the CSIRO, provides pasture management tools and real-time satellite data on pastures growth to support graziers to make better strategic decisions at the paddock level. However, technical (e.g. accessibility, scale, accuracy), social (e.g. lack of knowledge, distrust) and institutional (e.g. skills, lack of personnel, funding) pitfalls inherent in the adoption of spatial information and related technology by multiple stakeholders and diverse interests should not be underestimated. This issue will be explored in the discussion section.

4.4 Discussion

The primary purpose of this chapter was to assess the current stage of public participation process by investigating the practical strategies, mechanisms and tools used to engage with stakeholders within the scope of the WQIP. In doing so, it addressed the extent to which mapping information and spatial technologies are used to gain access to information and to support stakeholders' engagement in natural resource management.

The findings of this chapter are largely consistent with the wider literature about the growing demand, but inconsistent implementation of participation strategies in natural resource management (e.g. Buchy & Race 2001; Chase 2004; Lawerence & Deagen, 2001; Larson & Lach, 2008). As the results showed, participation is often seen from the funding agency's perspective and it is perceived by most stakeholder groups as a pre-defined process developed to address legislative requirements and political agendas. In most of the documents analysed and

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[8] Envirofund is an Australian Government funding scheme established in 2002 to support community groups and individuals to undertake small projects aimed at conserving biodiversity and promoting sustainable natural resource use. Further information can be found at http://www.nht.gov.au/envirofund/. Last accessed: 14/06/2009.

[9] Formally called 'Pastures from Space' website provides satellite data on estimates of pasture growth rate (PGR) to support the livestock industries of Australia. Further information can be found at http://www.pasturesfromspace.csiro.au/. Last accessed: 14/06/2009.

situations investigated, participation does not go beyond the level of public consultation and involvement.

The designated role of regional bodies to bridge the gaps between government and community and to involve diverse sectors of the community in the management of natural resources has been made through the development of funding programs, tender incentives and grant schemes. On-ground engagement with stakeholders is increasingly based on indirect interaction throughout contracts, consultancies, and the support of volunteer organisations. The provision of extension support and the implementation of on-ground services (including training, field days, demonstration site activities) have been restricted by funding and short term positions.

Results also demonstrated that spatial data and geographic information tools constitute a useful way to collect data, to facilitate access to information, and to support communication of land-use planning and water quality management activities. However, differences in stage of use and usefulness of spatial data and related technologies were found between management bodies and other stakeholder groups. While the NQ Dry Tropics body has mainly used mapping information and GIS technology to inform (e.g. BWQIP Catchment Atlas), consult (e.g. mapping exercises to collect environmental values) and involve (e.g. training workshop sessions) stakeholders in planning and management, stakeholder groups, such as landholders and growers, mainly use mapping and spatial information to satisfy government requirements in applying for permissions to make changes in management of their property.

The following discussion focuses on some of the aspects of social, institutional and technical fits and misfits of participation in natural resource management. It also discusses the role of spatial information and GIS related tools in bridging gaps in information and communication processes and to support participation in land planning and water quality management issues.

Fits and Misfits of maps, spatial information and participation in natural resource management

Participation in land-use planning and water quality management

It has been argued that the engagement and meaningful participation of different stakeholder groups in the decision making process ensures legitimacy, enhances acceptance, increases satisfaction, improves transparency, promotes awareness of natural resource management, and reduces conflict among stakeholders (e.g. Croke *et al.,* 2007; Jonsson, 2005; Lawerence & Deagen, 2001; Webler *et al*., 2001). There are also widely held assumptions that enhanced access to information fosters stakeholder involvement (Nyerges *et al*., 2006) and that high levels of participation are more effective and preferable to lower levels (Ravetz, 1999; Ross *et al*., 2002)

Findings of this study showed that a stable and continuous relationship with the management agency and between stakeholders is the most effective way to ensure information flow and to connect people in land management practices and water quality issues. However, such relationships are complicated not only by multiplicity of institutions, limited funding and tight timelines, but also by an inadequate engagement process. High expectations of change and continuous relationship (Buchy & Race 2001; Jonsson, 2005), which are usually not maintained and consultation fatigue (Diduck & Sinclair, 2002; May, 2005; Reed *et al*., 2008; Richards *et al*., 2007; Smith & Craglia, 2003) are significant deficiencies in public involvement processes. Reed *et al.* (2008) emphasised that consultation fatigue is an indication that, although taking part in the process, stakeholders do not perceive that their involvement has influenced the decisions made. Stakeholders might become sceptical about participation by believing that the process was just to legimitise an upfront decision, regardless of their involvement (Richards *et al.,* 2007). Consequently, community engagement exercises results in low response rates (May, 2005).

Both reasons were found in discussions about what constitutes an effective engagement program in natural resource management. About expectations, participants reported that *"We have done these things many times before, but things do not seem to change, government does what they want to do"*. In another occasion, in a workshop about landholders' incentives to improve water quality, a participant questioned *"What will Burdekin Dry Tropics do with this report?"* and the workshop facilitator answered "*Have more research and funding, have things happening on the ground".* In regards to overconsultation (consultation fatigue) a participant noted *“Last month there were three surveys going on, so farmers ask: do you do not talk to each other? Lots of consultation seems to going on but not much is reflected on the ground".* In addition, in a meeting of the WQIP Steering Committee, which involved a dialogue about nutrient runoff and the linkages between reef and catchment plans, a farmer representant stressed that “*stakeholders’ participation and communication, adaptive management issues are nice things but no practical things happened. We still need better ways to communicate information about water quality issues”*.

Multiplicity of institutions with overlapping policies and roles has fostered people’s shared perceptions of lack of transparency, confusion and uncertainty about existing institutional arrangements and the purpose of management plans (e.g. Everingham 2009; Marfo, 2008; Sikor & Lund 2009). In Australia, ambiguity in the roles and responsibilities of different bodies (e.g. catchment committees, regional development organisations) and levels of government (Federal, State/Territory and Local) gained prominence in the 1990s when regional organizations were established (Everingham 2009). Action at a regional level was recognized as a necessary form of decentralization, and many government policies and programs have resulted in the formation of regional organizations with governance roles. Everingham (2009) observes that such decentralization has resulted in proliferation of functionally, but also uncoordinated boards and committees operating with different boundaries and reporting arrangements at the regional level. These complex and multilayered governance structures were not coordinated and did not operate with consistent boundaries resulting in duplication, inconsistencies and contradictions for governance of natural resources. This ‘congestion’ of multiple players or ‘institutional void’, as defined by Everingham (2009), resulted in diffused governance responsibilities causing confusion for people and, consequently, reduce people’s interests and willingness to participate in the management process.

Results of the present research showed that, overlaps and redundancy in institutional arrangements still influence public participation in land-use planning and water quality management. Lack of cooperation and coordination between agencies, multiplicity of groups and fragmented programs represent a major policy challenge. The increased number of committees reported in this study as one of the information and communication strategies currently used to promote participation has caused stakeholders’ frustration and decreased interest in participation. Different committees have been formed in an isolated way acting independently in a variety of disconnected projects (e.g. soils, water, vegetation) and fragmented actions. Overlap of representative members among those committees was also recognized as a problem.

A balanced and diverse representation of stakeholder groups and interests was also perceived as important in decision processes. Representatives of local government and industry, for instance, agree that the WQIP Steering Committee is a suitable tool to support participation and involvement in natural resource management. However, they also think it is necessary to optimise the representativeness of people in such groups because the presence of different stakeholders is a critical way to disseminate information. Results showed that people involved in the WQIP are not satisfied with the increasing number of committees mainly because of the great overlap of interests and people represented in these groups. Concerns were often expressed about whether representatives of the WQIP committee would actually convey the learning and outcomes of the committee back to their constituents and their respective areas of interest. Several authors have discussed representativeness in environmental decisions. In Queensland, Whelan & Oliver (2005) argued that several regional groups have problems achieving or maintaining an adequate participation of community sector interests and in organisations. They found that the board membership of most regional NRM bodies was imbalanced and over-represented by industry and local government authorities, while grassroots groups were under-represented. In another example, Larson & Lach (2008) identified that individuals who participated in place-based groups of land-use planning and water resource protection, in the region of Johnson Creek watershed of metropolitan Portland (Oregon), were not representative of the broader non-involved public. In this case, residents who participated in the watershed council were more supportive of water resource protection than non-participants.

Another misfit found in the land use and water quality management process in the Dry Tropics NRM coast is the institutional model of short-term funding of one year positions for extension and engagement officers and the reported social need of stakeholders for long-term networking and improved relationships across organisations and stakeholder groups. Such misfit has resulted in discontinuity and loss of momentum in engaging stakeholders in natural resource management processes. The findings demonstrated that the reliance on the project officer and more direct contact with the management organisation are important factors influencing the implementation of best management practices and engagement in land use planning and water quality improvement processes. As a respondent stated: *"... Staff shifting and short timeframes are still the biggest problems for a stable relationship and ongoing communication process with the community"*. Other participants added: *"Connections are made with individuals inside the organisations and not with the organisation itself. It is personality driven instead of institutional driven"*. In a more detailed statement, an older landholder said "*"In my time the department only used to consult with people on the ground, but it is all gone now. It is pretty disappointing you've got to go to 10 meetings which end up to 6 and then all the rules and everything else are validated without any consultation. They [government] have the money to do a consultancy in a* *certain amount of time and it is got to be written down"*. Although identified as a community organisation, regional bodies, such as the NQ Dry Tropics NRM, are funded by government programs, so it is the government in each state who defines the investments in extension staff and on-ground services. Interview data found that historical fluctuations between extension service investments at the enterprise level and broader planning strategies supported by cost-effective consultancy are attributed as major reasons for decreased participation of key stakeholder groups such as growers and graziers.

The indirect interaction with stakeholders and instability on the provision of on-ground services are consequences of the regionalisation of natural resource management and extension services in Australia. The shift from a Landcare dominant paradigm (1986-2000) to an emerging regional groups approach (2000 onwards) altered the individual and small farm groups based work to an allocated resources delivery on-ground work (Moore & Rockloff, 2006). While criticised by stakeholder groups, some authors argue that the use of third party consultancy schemes and highly skilled facilitators may be advantageous to maintain impartiality of the decision process and to better deal with conflicting situations, for example between conservationists and resource users (Reed *et al.*, 2008). In this regard, Thomson and Alisson (2006) stated that employed consultants can assist with the development of regional strategies and investment plans, mainly because of the tight timelines and a lack of capacity within the natural resource regional bodies. However, they also underlined the disadvantage of retention of knowledge and understanding of the engagement and planning processes by independent consultants.

Lack of trust in the management agency, mainly the result of dissatisfaction from previous experiences, was also found to be an important factor influencing participation in land use and water quality practices. Field observation data and document analysis showed that concerns with the 2004 Rezoning of the Great Barrier Reef and the related consultation process have affected people's trust in management agencies. For instance, on different occasions during the consultation mapping exercise of the environmental values project - WQIP people expressed issues such as "*They [the GBRMPA] wanted to take from us without putting anything back. The green zones stuff, you know. They closed areas we used to fish. So, we are concerned about zoning in the freshwater too"*. These results corroborate previous research identifying trust as a key component in the relationship between state management organisations and resource users in natural resource planning initiatives (Beierle & Konisky, 2000; Craig & Vanclay, 2005; White, 2001). Beierle & Konisky (2000), for instance, concluded that the high and significant relationship between agency's commitment and building of trust was essential in reducing conflicts of public participation in the environmental planning process in the Great Lakes region. In the Australian regional context, despite efforts encouraging participatory processes, such as the establishment of numerous deliberative committees, satisfaction with NRM outcomes or the decision making process has been undermined by stakeholders' mistrust in government intentions to provide a genuine opportunity to influence decisions (Craig & Vanclay, 2005).

Additionally, the inappropriate use of technical-scientific language was also found to be an important issue influencing the way stakeholders' interact in land use planning and water quality management. The use of technical jargon in reports and other communication material about water quality and nutrient concentrations used in the development of the WQIP were reported as unsuitable by farmers in the Lower Burdekin region. As a sugar cane farmer observed during a WQIP Steering Committee Meeting: *"There is a lack of coordination in scientific jargon. We need to understand common jargon terms used such as inorganic nitrogen and its associated values. I do not need to read a website to understand that"*. For instance, Petts & Brooks (2006) emphasised the fact that the overuse of technical jargon in air quality management in England has caused public frustration and decreased acceptance of the scientific information provided. Within the scope of the WQIP, collaboration between the NRM body and a local research institution to produce a short friendly document was reported to be a step forward to minimise the use of technical jargon so as to better communicate with its stakeholders.

Last, but not least, this research found that reluctance of the natural resource management agency, the Burdekin Dry Tropics NRM, to be analysed represents an additional institutional barrier to participation. In the course of data collection for this study, concern was raised over a short survey provided to participants of a workshop organised by the management agency. The survey, an adapted version of survey provided to WQIP related groups, aimed to explore the views of managers and decision-makers about public participation and get their views on the usefulness of use mapping and geospatial information technologies to support access to information and to facilitate public engagement in the management of natural resources. From the 22 surveys distributed, 3 were returned unanswered and only 1 (from non-NRM staff) was completed. The questionnaire was perceived as an institutional evaluation instead of a research related activity. Some authors have discussed organisational resistance to engage in evaluation (e.g. Gordillo & Andersson, 2004; Taut & Brauns, 2003). For most organisations, evaluation is perceived as a pressure or a control measure commonly associated to the need of structural changes or the loss of power (Taut & Brauns, 2003). Such attitudes might reflect a limited openness of the organisation, in this case a natural resource management agency, and potentially restrict the capacity of participation to influence decision making. This misfit also needs to be addressed if the gaps between discourse and practice of an inclusive and effective community involvement are to be overcome.

Is there a fit for spatial information and GIS based tools in supporting stakeholders' participation in the Dry Tropics NRM?

Current and projected management scenarios in land use planning and water quality management processes provide a promising context for the use of spatial information and GIS based tools for the natural resource management in the Burdekin Dry Tropics. Results showed that the use of spatial information and related technologies is growing, as well as the potential for facilitating access to information and supporting communication in land and water management processes. Map-based interviews, training workshops, provision of satellite imagery, and development of online atlases represent some of the mechanisms in which spatial information and GIS add value to the flow of information and influence communication and interaction between stakeholders.

It is widely advocated that geo-information and GIS contribute to facilitation of information flow and to support dialogue between stakeholders in NRM (e.g. Bussink, 2003; Gouveia *et al.,* 2004; Jankowski *et al*., 1997; McCall 2003). The visual representation of mapped information integrated with GIS manipulation (e.g. data collection, input and storage) and analytical capabilities (e.g. manipulation, analysis and synthesis) provides a useful approach to support planning and participation in resource decision processes (e.g. Balram *et al.,* 2009; Balram & Dragićević , 2006; Haklay & Tobón, 2003; Kliskey, 1995). For instance, in the management of three catchments in the Peruvian Andes, Bussink (2003) reported that the integration and display of coupled mapping and GIS was an effective tool used in community workshops for motivating stakeholders and building awareness about natural resources. In this case, parcel-level land use maps and spatial integration of different biophysical criteria supported farmers to better understand the potential for pasture improvements and to prioritise soil conservation and potential production areas. Nevertheless, mismatches of social (stakeholders focus more on parcel level rather than on catchment scale issues) and spatial (scale of the database available not sufficiently detailed to spatial modelling) scales, and the need of expert knowledge for geometric correction of aerial photographs, limit the adoption of spatial data and GIS tools by farmers and decision makers in the Andes region.

The findings reported in this chapter also indicate that technical (e.g. accessibility, scale, accuracy), social (e.g. lack of knowledge, distrust) and institutional (e.g. skills, lack of personnel, funding) misfits still restrict the adoption of spatial information and related technology by multiple stakeholders groups. Furthermore, results suggest that GIS and spatial systems are used mostly within government and research related organisations, while the majority of landholders in the region still use traditional mapping information to fulfill government requirements in land use planning. Most of the tools used are still the paper maps and basic spatial equipments such as GPS. At the individual level, spatial information and GIS based tools are still costly (not so much in relation to money as in the past, but in terms of time consumed to reach the proper sources and get the information in an adequate time) and require a certain level of technical skills to understand and use spatial related tools. Therefore, for most grassroots stakeholder groups, GIS technology is still peripheral to their immediate needs (Figure 4.14).

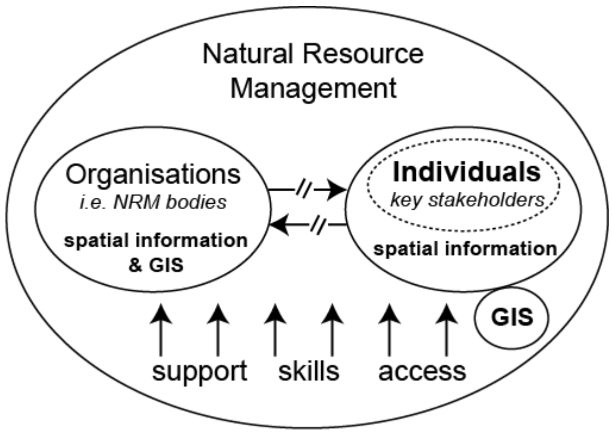

Figure 4.14. Schematic representation of organisational and individual spheres and interaction with spatial information and GIS. Uninterrupted arrows indicate major restrictions and break off arrows represent inconsistencies and discontinue linkages between organisations and individuals on information exchange.

As represented in Figure 4.14, the connection between organisations and individuals on the use and transfer of spatial information and GIS technology is not a continuous process. Instead it has been represented by a fragmented approach in which spatial data and GIS technology are used only to provide information or to get feedback in a consultation process. In most cases, mapping information presented to participants is at a too coarse scale or not updated, lacks accuracy and on-ground validation.

In assessing the role of spatial information in communicative regional resource use planning in the Queensland's Central Highlands, Bischof *et al.,* (1999) identified that technical approaches still dominate regional resource use planning processes in Australia. Similar to the findings of this research, Bischof *et al.,* (1999) noted that the use of spatial information has been restricted to the technical agencies undertaking the planning, while in practice the interaction with natural resource stakeholders is limited to meetings or public comment on the outcome of the planning process. In regional resource use planning in the Central Highlands, capacity building has enhanced individual and institutional ability to understand complexities of scale, classification issues and use of spatial information and tools. This has allowed better incorporation of spatial information into the NRM planning and decision-making processes within the region.

Additionally, results from this study also indicate that mistrust in both the NRM organisation and the spatial information used in the communication and consultation processes influence stakeholders' interaction with land planning and water quality management issues. Mostly, both at interviews and observation at meetings, people expressed great concern about how and for what purpose the map-based information they provide would be reported and used within the context of the water quality improvement plan. In previous research about air quality information in England, Bush *et al*., (2001) reported that distrust towards the motivations of the government in interpreting and presenting the data, as well as specific issues about complexity, ambiguity, validity and spatial scale resulted in low usage of the information available. In another study, Bischof *et al.*, (1999) also found that stakeholders tend to mistrust spatial information and not use it if they are supplied with facts and information that oppose their understanding and beliefs about the natural resource. This fact tends to increase conflict between stakeholders, instead of empower stakeholders and democratise the planning process.

Finally, interview data also revealed that the use of a 'commodity specific' approach is a significant problem for the wider adoption of spatial information and GIS based tools in natural resource management. It means that each specific areas (e.g. grazing, sugar, fisheries) have its own arena of support extensions and GIS applications. There is, therefore, a growing need to consolidate and better manage spatial imagery datasets and related technology in the Burdekin Dry Tropics coast. The establishment of GIS collaborative joint initiatives such as the Herbert Research Information Centre (HRIC), located in the Herbert River catchment region in the Wet Tropics coast, represents a successful example in the integration of efforts within and across interested stakeholder partners in the management of spatial imagery and GIS.

The HRIC GIS community-based collaborative joint venture started in 1993 with the Herbert Mapping Project to address constraints of data inadequacy to stakeholders' needs and associated costs of acquiring spatial data. It was a response developed between 11 agencies (industry, community, state, local and federal government) to fund the acquisition of digital orthophotography, cultural (e.g. farm boundaries), natural (e.g. streams) and cadastral data for the lower catchment (Walker *et al.*, 2001). Later on in 1996, a cost-benefit analysis demonstrated the appropriateness and viability of a collaborative approach. Consequently, six stakeholder groups, four stakeholders representing the local industry and community (CSR

Sugar Mills, Herbert Cane Protection and Productivity Board, Hinchinbrook Shire Council and Canegrowers Herbert River Executive) and two representing the government state (Queensland Department of Natural Resources) and federal government (CSIRO) signed a ten year collaborative agreement (Walker *et al.*, 1998).

Since its first project the HRIC community-based GIS model has managed the acquisition, integration and dissemination of geographic information and fostered the effective use of GIS amongst the joint venture partners (Walker *et al.*, 2002). Among the key components that avoided potential barriers to effective collaboration and conflicts of interest are the agreement on common goals, neutral location of the infrastructure, credibility, self-funded, staffed by high skilled people, and medium to long-term commitment (Pyper, 2000). A three year evaluation program revealed that participants gained better understanding about the potentialities and limitations of spatial data and its applicability (Walker *et al.*, 1998). Furthermore, collaboration seemed to have fostered co-operation between agencies, improved data quality and data access, and supported better informed decisions in resource management in the Herbert catchment. However, intellectual property and liability issues, and data access policies amongst partners and within government agencies, still represent significant challenges to overcome.

Results of this study showed that demand for spatial information and GIS is growing in land use planning and natural resource management in the Burdekin Dry Topics region. It also found that further adoption will depend on better integration and long-term capacity building and support, instead of a fragmented and ‘commodity specific’ approach. The need of a stable body that translates and provides relevant spatial data and technical support in a timely and cost effective way is an important issue for stakeholders in the studied region. Collaborative models such as the HRIC in the Herbert River catchment may fill the gap of insufficient expert support, need for a centralised information database, mismatch of scales, distrust on mapping and spatial data found in the Burdekin Dry Tropics NRM context. The use of existing structure and established community-based networks such as the one represented by the Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc. (BBIFMAC) can be a beneficial starting point to facilitate spatial data acquisition and access.

4.5 Limitations of the Research Findings

Results of the present study provide relevant data on participation strategies and tools used to engage stakeholders in the context of the development of the Burdekin WQIP. It also addressed the needs, limitations and potential of the use of mapping information and spatial technologies for facilitating access to information and supporting communication in land and water management processes. Nevertheless, it is important to recognise the limitations of the study.

First, the major limitation of this study is that it only focused on a portion of the stakeholder groups' population. While the term "stakeholder" is used throughout this chapter in describing respondents, the studied population is more accurately described as people who were accessed and selected within the scope activities related to the WQIP.

A second limitation was that the small sample size of the survey data limited the use of statistical analysis. In addition, the sample was purposive, not random, limiting ability to generalise from the findings. The small sample size was primarily the result of the respondents selection strategy adopted. Because of previous problems caused by multiple and simultaneous consultation activities in the region using mail-based questionnaire, respondents demonstrated reluctance and lack of interest in providing their information using similar techniques. Therefore, this study adopted a more specific approach based on interviews and observation, and a follow-up short-survey distributed at meetings, training sessions and workshops for those who demonstrated interest in the research subject. Further distribution of the questionnaire directly to stakeholders' properties, mainly in the case of farmers and graziers, was limited by costs and large travel distances. An online version of the survey and an interactive forum tool were designed as an additional opportunity to collect information and for people to share opinions on the use of mapping and spatial information techniques and participation issues in NRM. However, it received a low response rate.

These limitations aside, the results of this chapter enhance understanding of the current stage of public participation within the scope of the WQIP, including practical strategies, mechanisms and tools used to engage with stakeholders. It also highlights that, although the use of spatial data and geographic information technology is still limited, the need for better spatial data quality, consolidated datasets and extension support is increasing.

4.6 Chapter Summary

This research points to the importance of both socio-institutional and technological factors in shaping the functionality, relevance, and context of spatial data and geographic information technologies, and their accessibility to a variety of potential grassroots data users in the Burdekin Dry Tropics NRM coast. The core constructs in this context are represented by stakeholder' participation in water quality targets setting and the use of mapping, satellite imagery and GIS to inform and collect stakeholders' input about environmental values and related water quality objectives. Results suggest that participation processes and use of spatial information and GIS tools in water quality management and decision making are highly influenced by a complexity of interlinked contextual factors represented by multiple and conflicting interests (e.g. degradation of riparian vegetation, improvement of water quality), previous experiences (e.g. perceptions of pre-determined decisions) and limited institutional support (e.g. insufficient extension personnel, incongruent timeframes).

Effective engagement and participation of stakeholders greatly relies on the management officer, established networks and personal relationships, and provisions of property-scale spatial information are important frames influencing a meaningful public participation process. However lack of skills, difficult access to information, tight timelines and government funding schemes, and instability of NRM and extension personnel were identified as main constraints to a participatory use of geo-information technology.

Spatial information and related technologies facilitate access to information and support communication in natural resource management. However the wide adoption of geographic information technology still faces considerable challenges. Within the studied context, GIS tools have been used mainly by environmental bodies, while most grassroots groups do not possess sufficient skills and support to understand the technology. In addition, the adoption of spatial data and GIS technology has occurred on a fragmented commodity basis in which different areas (e.g. grazing, sugar, fisheries) have their own arena of support extension and GIS applications.

Despite such issues, the results of this study provide important and valuable data to support the development of more appropriate ways of interacting (communicating and learning) with spatially-referenced data. Key findings indicate that many stakeholders are highly motivated and committed to influence decisions on natural resource management. It also revealed that demand for spatial information and geographic information technology in the land and water quality management process is increasing. These findings highlight that support for water quality management and reductions in land-based pollutant discharges into coastal systems could be enhanced by building trust and strengthening established networks between resource managers and key stakeholder groups.

The development of a comprehensive and collaborative engagement protocol during the project's scope phase would provide natural resource management agencies and stakeholders timely opportunities and incentives for long-term participation. Although based on case study specific approach, this study provides seven major practical lessons learned that can be generally considered as initial insights for the development of stakeholders' engagement and communication protocols in natural resource management:

- Lack of openness about the outcomes of the decision making process and uncertainty on the level of engagement required may lead to reduced trust and decreased participation. To overcome this situation, resource managers need to better articulate their intentions and determine tangible outcomes, while user groups have to better identify which role that they want to play in the process.
- Continuous and adaptive feedback between data collection and data delivery phases are critical to keep stakeholders' interest and engagement in land and water management practices. Resource users' expectations about the data collected from management institutions were found to be quite high within the scope of the WQIP. If there is a great delay between the data collection and feedback, stakeholders' interest can be lost.
- If regional groups continue to manage natural resources in a project-by-project basis approach, then short-term funding schemes and lack of long-term extension on-ground support will continuously affect the implementation of communication and engagement strategies in land-use and water quality management. Strong investment in trust building and strengthening established linkages needs to be developed independently of funding-related schemes and tight timeframes.
- Participation needs to be adopted as a means and a process, not as an end or a tool to fulfill legislative requirements. Therefore, the development of an engagement protocol should be embraced by the management agency as a permanent process. It has to be specifically adapted according to the different projects, but not a fragmented and project specific driven approach.
- Expectations that cannot be accomplished should not be raised. If the natural resource management body promises empowerment but has no resources or willingness to foster it, then frustrated expectations about change and influence in the final decisions may decrease participation in the future.

- Spatial data and geographic-related technology can be useful ways to support information and communication processes in land-use planning and water quality management activities. However, for the adoption of spatial data and geographic information technology, investments in capacity building, ongoing technical support, and centralised information storage and access need to be considered at the early stages of the planning process.
- Valuing stakeholders' support, for instance, by the simple provision of maps used in workshops and consultation mapping exercises may represent an immediate feedback of their input and the value of their participation. It may also stimulate spatial thinking and encourage the use of mapping tools.

Finally, studies of this nature would greatly benefit from further research on the use of an experimental design, in which control and treatment groups of stakeholders are exposed to different spatial-related information and tools. Alternatively, the effectiveness of geospatial technology could be compared with other ways of communicating such as media and printed reports.

Chapter 5

EFFECTS OF THE REZONING OF THE GREAT BARRIER REEF FOR RECREATIONAL FISHERS

Case Study 2 - A spatial and social assessment of management changes of the Great Barrier Reef rezoning for recreational fishers in Queensland

Abstract. Recreational fishers are a key stakeholder group in the Great Barrier Reef Marine Park, and one of the major local users of resources within the park. In 2004, changes in management of the Marine Park resulted in reduction in the amount of area available to recreational fishing, resulting in a spatial displacement of fishing effort and aggregation within the Marine Park. It also influenced fishers' opinions and support towards the rezoning process. This chapter investigates the extent to which management changes in the rezoning of the marine protected areas in the Great Barrier Reef has affected recreational fishing access to the marine resources and the spatial distribution of fishing effort within the marine park in the Northern Queensland region. It analyses fishers' motivations and perceptions of the public participation process and consultation techniques used in the management of fisheries and marine park-related issues. The chapter also addresses the importance and usefulness of spatial data and geographic information tools to reflect the effects of management changes in the allocation of recreational fishing effort within the Marine Park.

Chapter 5 has contributed with results to: McCook, L.J., Ayling, T., Cappo, M., Choat, H. De Freitas, D.M. *et al.*, (2010). Adaptive management of the Great Barrier Reef marine reserve network: a globally significant case study in marine conservation. *Proceedings of the National Academy of Sciences (PNAS) – Marine Reserves special issue.* P*ublished online before print February 22, 2010, doi:10.1073/pnas.0909335107.*

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5.1 Recreational Fishing and Marine Park Management

The Great Barrier Reef (GBR) is one of Australia's greatest marine environmental assets, consisting of a spatially complex network of over 3,000 individual reefs and islands and extensive inter-reef and lagoon areas covering a total area of over 350,000 km^2 (Johnson & Marshall, 2007). Most of the GBR is encompassed by the multi-use Great Barrier Reef Marine Park (GBRMP or the Marine Park) where activities within the Marine Park are managed by using a zoning system that regulates the type and location of different activities that can occur within the park. Zoning is an important spatial management tool used in conjunction with other management strategies (e.g. permits, statutory plans of management, special management areas, best environmental practices/codes of practice and partnerships with industry) for the conservation and management of the GBRMP (Day, 2008).

Recreational fishers are a key stakeholder group in the GBRMP, and are one of the major local users of resources within the park (Sutton, 2007). Recreational fishing activity is a popular use of the GBRMP with around 198,000 recreational fishers using the GBR, including catchment areas adjacent to the GBR (Commonwealth of Australia, 2006). The annual catch of these fishers is estimated to be around 8 500 tonnes. Recreational fishers are estimated to have spent between $80 million and $201 million in relation to fishing activities in 2003. Expenditure on recreational boat fishing in the Marine Park was estimated by the Queensland Department of Primary Industries and Fisheries to be approximately $100 million for 2004. The value of the recreational fishing sector associated with the GBR is estimated to be $240 million per annum on a Gross Value Added basis (Commonwealth of Australia, 2006). Major management plans affecting recreational fishing activity in the GBR include: (i) *Great Barrier Reef Marine Park Zoning Plan 2003 (Zoning Plan)*[10] , (ii) *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 (Qld),* and (iii) *Fisheries (Coral Reef Fin Fish) Management Plan 2003 (Qld).*

In 2004, a comprehensive rezoning of the GBRMP increased the amount of no-take areas (locally known as 'green zones') from less than 5% to 33% (Fernandes *et al.*, 2005) reducing the amount of area available to recreational fishing. The overarching aim of the rezoning was to protect the biodiversity of the GBR whilst minimising adverse impacts on resource users (Day 2002; Thompson *et al.*, 2004). The GBRMP comprises a large percentage of the area available to recreational fishers in the local area and consequently, the closure of fishing grounds was expected to affect fishers' access to marine resources. The rezoning of the GBRMP resulted in

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[10] The Zoning Plan 2003, enacted under subsection 32 (11) of the Great Barrier Reef Marine Park Act 1975 (Cwlth) (ComLaw Federal Register of Legislative Instruments, was implemented in 2004. It is widely referred as the 2004 rezoning plan.

some spatial displacement of fishing effort within the Marine Park. Conversely, many recreational fishers stand to benefit from the increased protection of fish stocks and other resources which should enhance sustainability and, eventually, result in improved fishing in the Park (Sutton, 2007).

Integrated with the rezoning process of the GBR was a two-phased community consultation process that was strongly supported by spatial information in the form of zoned map-questionnaires as the main tool for gathering public input about the use of the GBRMP and opinions on the locations of proposed new no-take zones (Lewis *et al.*, 2003). Additionally, the aggregation and analysis of numerous map-based submissions and proposed new boundaries was done by geographic information system (GIS) tools and spatial analysis techniques through the collection, storage, analysis and display of spatial-based information (Fernandes *et al.*, 2005). Finally, GIS tools and datasets were critical to the publication of maps and legal boundary descriptions and the resultant zone maps used to communicate with key stakeholder groups (Fernandes *et al.*, 2005).

The management agency responsible for the consultation process, the Great Barrier Marine Park Authority (GBRMPA), received over 31 500 map-based submissions (representing the largest planning exercise undertaken in marine conservation up to that time) (Day 2002; Thompson *et al*., 2004). A public awareness campaign (including public meetings, workshops, and informational material) and expert knowledge were also used in the process (Fernandes *et al.*, 2005). Additional efforts were also adopted to overcome critical communication barriers (e.g. reluctance to accept zoning as the preferred management tool; lack of awareness about the complexity of the problem; lack of trust in government agencies) (Thompson *et al*., 2004).

Despite the extensive spatial consultation and analysis, previous research showed that most fishers were substantially impacted, and experienced at least some negative impacts from the rezoning changes (Sutton, 2008). For instance, fishers expressed negative perceptions towards the public participation process and dissatisfaction with consultation techniques used to engage recreational fishers in the rezoning plan. In addition, a majority of fishers reported that the new zoning plan has increased the number of people fishing in areas that remain open, and decreased their ability to access quality fishing areas in the GBRMP (Sutton, 2008).

Although it is not feasible to accomplish minimum impact and optimal solutions which equally satisfy the different users' needs in such a large area as the GBRMP, it is important to understand how well the spatially-based consultation reflected opinions and reduced the impact of the rezoning on Marine Park users. More information is also needed to better understand the effects of restricted access to fishing areas on the distribution of fishing effort within the Marine Park. In addressing the main social, institutional and technical aspects of the consultation process and techniques used in the 2004 rezoning, this study provides Marine Park managers with useful information about the implications and perceptions of the consultation process on the recreational fishing community. It also provides fishers with improved understanding of the extent to which their interests were considered in the Zoning Plan and how their fishing choices are affected by the implementation of no-take areas. Finally, results of this chapter will also provide a practical set of contextual factors, process, concepts and frames that influence recreational fishers' participation and attitudes towards the management of marine resources.

This chapter aims to assess and document observed spatial and related social implications of the 2004 management changes of the GBRMP on recreational fishing activity and recreational fishers. It analyses how the closure of fishing areas influenced the spatial distribution (e.g. spatial choices, fishing effort displacement and aggregation) of recreational fishers. It also investigates fishers' motivations and perceptions with respect to the public participation process and consultation techniques used in the management of fisheries and marine park-related issues. The chapter concludes by discussing the usefulness of mapping based data and geographic spatial analysis in exploring and describing those changes.

Integrating Fishers Spatial Knowledge and Geographic Information Technology in Marine Planning: an overview

Recent studies in marine planning increasingly acknowledge the importance of engaging those resource users affected by the design and implementation of marine protected areas (MPAs) (Baelde, 2005; Dalton, 2005; Drew, 2005; Granek *et al*., 2008; Lloret *et al.*, 2008; Sumaila *et al.*, 2000; Suman *et al*., 1999). Fishers, in particular, are amongst the key stakeholder groups to be affected by the implementation of no-take MPAs (Dalton, 2005; Suman *et al.,* 1999). The use of GIS and spatial analysis is continuously growing as decision support tools in marine and fisheries management, such as for stock assessment, analysis of fishing effort, species distribution, and population dynamics modeling (Babcock *et al.*, 2005; De Freitas & Tagliani, 2009).

Clearly, both public participation and the support of geographic information techniques are critically important to selecting and implementing effective MPAs (Pomeroy & Douvere, 2008; Portman, 2007; Scholz *et al.*, 2004; St. Martin, 2004). Nevertheless, the integration of public participation and people's spatial knowledge with geospatial analytical tools is still in its early stages in marine planning and fisheries management (Aswani & Laure, 2006; Hall & Close, 2007; Scholz *et al.*, 2004; St. Martin, 2004). Some examples are provided as follow.

In the North-Central Region of California, Scholz *et al.* (2004) applied an iterative process using a combination of semi-structured interviews and geospatial analysis for eliciting and integrating fishermen's knowledge into the MPA planning processes. The results allowed them to better understand past conflicts around MPAs, as well as to identify areas of high biological diversity, acceptable closure candidates, and fishing effort distribution. For instance, the comparison between the fishermen-identified areas with the initial set of government draft maps showed significant overlaps between critical economic areas and the MPAs, and between acceptable closure candidates and the initial draft map. Those findings explained past controversy about the draft maps release by the government in 2001 in which, by using logbook records of fishermen's catches and targeted species as habitat proxies, designated some of the economically most important areas off the coast for closure.

Public involvement in the design and management of cross-border protected areas in the northern Gulf of Aqaba was greatly supported by the use of spatial multi-criteria tools (Portman, 2007). Spatial multi-criteria analysis was used to combine terrestrial (e.g. non-point pollution sources) and marine (e.g. biodiversity, water quality) parameters with stakeholder preferences to identify areas most suitable for varying levels of protective zoning in the Red Sea Marine Peace Park. The resultant different map-based scenarios proved to be an effective visual output which were easily understood and modified, reducing complexity and facilitating discussions of jurisdiction and location of marine reserves between Jordan and Israel.

The integration of local (harvester) and scientific (researcher) knowledge with multi-layer GIS database and spatial analysis was used by Hall & Close (2007) to produce a fishing likelihood surface to identify high pressure harvest zones of small-scale fishery of spiny lobster in the Turks and Caicos Islands. The GIS-centered method combining map-based interviews and multiple buffers allowed the identification of areas of potential overfishing that may require specific management strategies to ensure their long-term viability. Most importantly, it improved the community's understanding of the marine resources and their ability to manage and develop the resource base.

A combined interview and GIS approach was used by Daw (2008) to collect fishers' knowledge about the spatial and behavioural aspects of fishing effort distribution by artisanal lobster fisheries of the Corn Islands (Nicaragua). The study showed that spatial effort distribution and fishing strategies varied between sectors, with the highest proportion of the fishers concentrated beyond 10 miles in the northern zone. It also highlighted those understanding artisanal lobster harvesters' spatial perceptions as well as the factors underlying spatial effort distribution which can better support the prediction of MPA impacts on fishers and resources in terms of displacement of fishing effort.

Although research exists that integrates different levels of participation and resource users' information with spatial data and tools, it is still uncertain whether such integration has incorporated the concerns of users, such as recreational fishers, and supported a meaningful engagement in marine park planning and management.

Specific Aims

The aims of this chapter are to:

(i) assess the potential of PPGIS tools in documenting and reflecting the implications of the observed spatial changes (e.g. concentration of fishing effort in remaining open areas, shift of fishing effort into previously under exploited areas, and changes in travel distances to fishing grounds) in the distribution of recreational fishing effort in response to the 2004 rezoning of the GBRMP,

(ii) evaluate the extent to which recreational fishers concerns were incorporated in the rezoning process, and

(iii) analyse fishers' motivation to engage in the management of fisheries and the GBRMP, their perceptions towards the public participation process, consultation techniques used, and the usefulness of mapping information and spatial tools.

5.2 Data Collection and Analysis

Design and Gathering

Data used in this chapter were collected in conjunction with a state-wide recreational fishing survey conducted by the Fishing and Fisheries Research Centre at James Cook University. The overall aim of the state-wide project initiated in 2005 was to investigate the effects of the recent rezoning of the GBRMP on the recreational fishing community. To achieve this, *spatial data* (e.g. previous and current fishing locations) in reef-use patterns (distribution and locations fished) were collected using face-to-face map-based semi-structured interviews at two specific sites, Townsville and Rockhampton (Fig. 5.1). *Non-spatial data* (e.g. fishers' motivations and reasons for participating, their beliefs, opinions and involvement in fisheries and marine park management, and the usefulness of public consultation techniques) were collected using a combination of telephone and mail survey methods from a representative sample of recreational fishers across the GBR area in Queensland (Fig 5.1). Both data collection methods as described as follows.

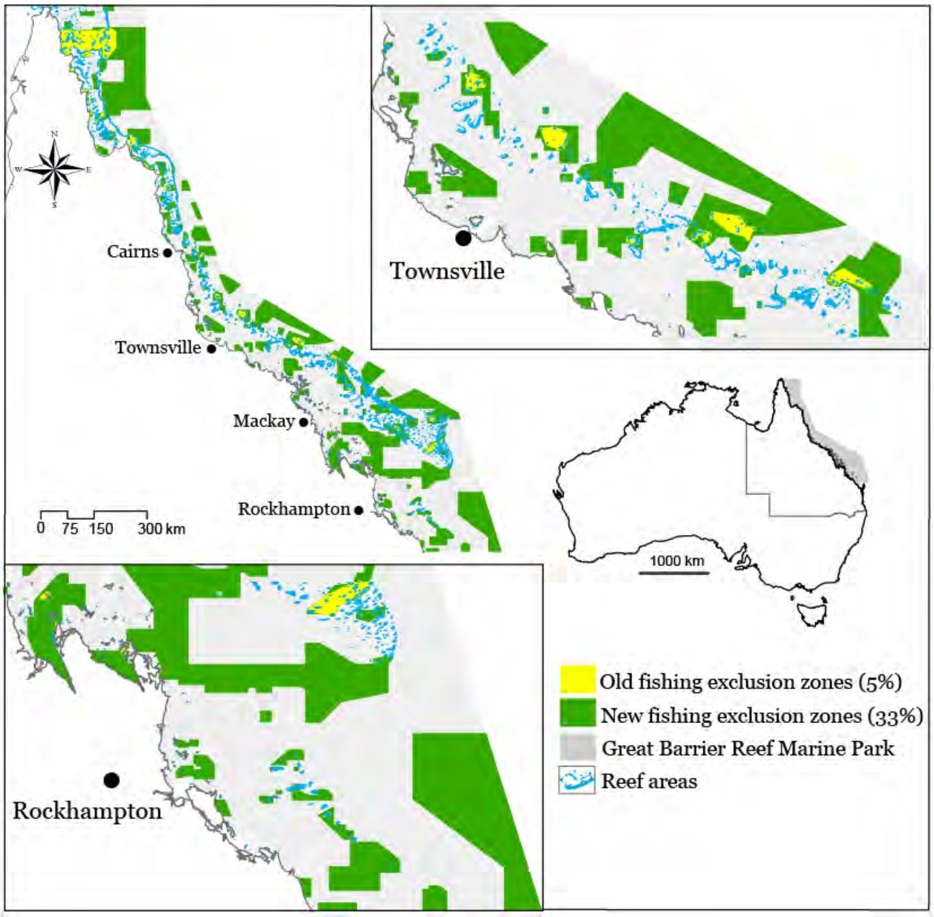

Figure 5.1. Map of study area showing the extent of the study area, as well as old and new fishing exclusion zones (green zones). Detail of the map-based interview sites are shown in the insets.

From here forward, the words 'previous', 'pre-rezoning', and 'before' will be used interchangeably to refer to locations that fishers used to fish prior to the implementation of the 2004 rezoning but that were "lost" because of the increase in no-take areas. Likewise, the words 'current', 'post-rezoning', and 'after' will refer to locations used by fishers that remain open to fishing. 'Fishing location' and 'fishing spots' will be used to refer to the different sites provided by fishers as polygon shape in the zoning maps.

Data design and collection, processing and analysis were on-going and iterative processes, by which fishers' feedback and preliminary analysis of the data collected oriented further data collection and analysis (Fig. 5.2).

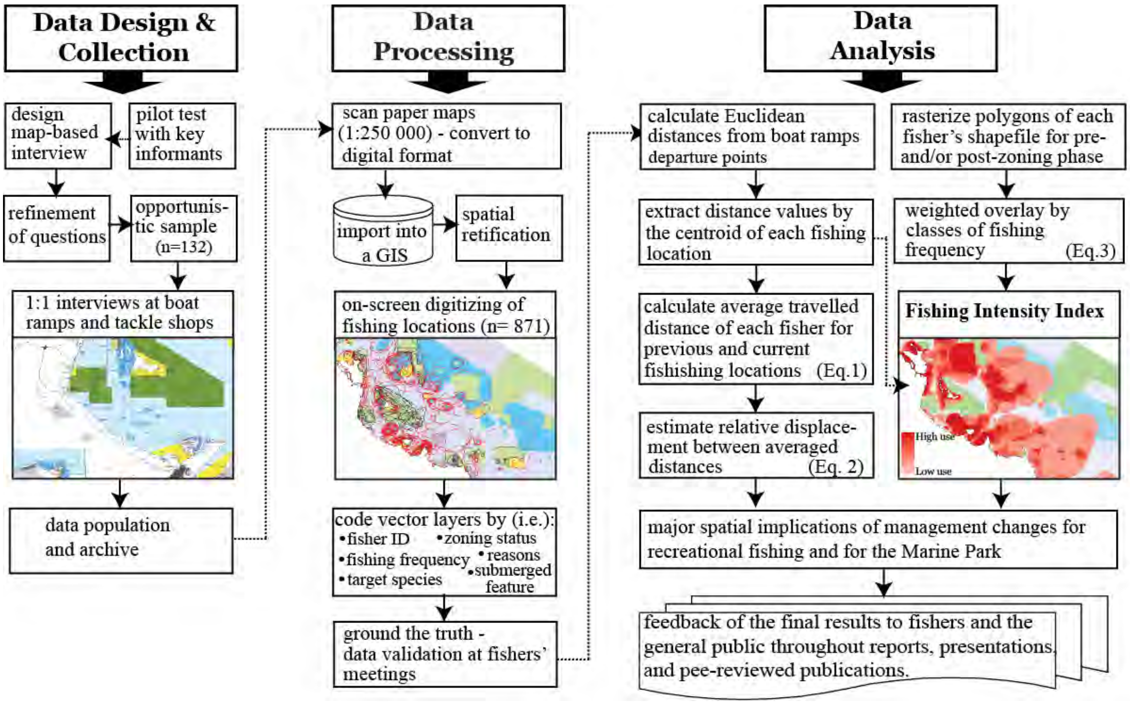

Figure 5.2. Schematic outline of the main components of data collection, processing, and analysis.

Spatial data: map-based interviews

Face-to-face interviews were conducted in Townsville and Rockhampton from March 2006 to December 2007. The coastal and nearshore waters of Townsville and Rockhampton regions are particularly important recreational fishing locations at the Queensland coast within the GBRMP (Fig. 5.1). Both sites are remote regional centres in which tourism and fishing play an important socioeconomic role. While Townsville is located on the north-eastern on tropical coast of the Dry Tropical coast, Rockhampton lies just north of the Tropic of Capricorn on the central Queensland coast. Of particular relevance for fishing activity are the presence of the Burdekin River system near Townsville and the Fitzroy River system in Rockhampton. The presence of fresh, inland and coastal water and the reef system provide fishers with diverse fishing habitats and fish species.

Respondents were opportunistically approached at boat ramps and tackle shops by trained interviewers who presented a brief overview of the project and asked about their interest in participating in the research. Once a recreational fisher agreed to an interview, the interviewers arranged an appropriate place and time to conduct the interview. All fishers were interviewed voluntarily with the understanding that individual answers would not be identified and that the results would be presented in an aggregated form only.

An 8-page semi-structured interview (see Appendix C) [11], conducted with 132 respondents in the two study sites, was pilot-tested and refined prior to data collection. To address spatial changes resulting from the rezoning, pre (previous) and post (current) fishing locations were recorded on paper GBR zoning maps (scale 1:250, 000) using the interview map-biography method which uses maps and mapping methods as the main medium of the interview process (Close & Hall, 2006; Hall & Close, 2007). While the interviewer collected respondents' answers to the semi-structured questions (e.g. species catch/target in each location, specific reasons for select that location), interviewees were requested to draw on the zoning paper maps their favourite locations (e.g. places where they fish the most, places where they catch the most fish) previously and after the rezoning process. Fishers were specifically asked to identify any areas that they used to fish on a regular basis (prior to the rezoning) and that were subsequently rezoned as "no-take" areas under the rezoning implemented in 2004.

[11] Appendices are in Volume 2 of this thesis.

Non-spatial data: Telephone and Mail Surveys

The mail survey addressed more general questions about fishers' motivations and perceptions of the rezoning consultation process and the techniques commonly used to inform and consult people about fisheries and marine park management changes.

Recreational fishers aged 15 years or over residing within 50 km of the GBRMP (from Cairns to Rockhampton) were surveyed during February and March, 2007. A list of active fishers in the GBR region was not available; therefore a random sample of residential telephone numbers was selected from the current White Pages covering the study region. Duplicate numbers and mobile numbers were excluded from the sampling frame prior to sample selection. Fishers were administered a short survey about their fishing activity and at the conclusion of the survey, respondents were asked if they would be willing to participate in a follow-up mail survey. Survey procedures were similar to those recommended by Salant & Dillman (1994), with the exception that an introductory letter was not sent to fishers prior to the first survey. A total of 800 completed mail surveys were returned and an effective response rate of 55% was achieved. This methodology has been used previously to collect social data from recreational fishers in Queensland (Sutton 2008; Sutton, 2006a).

An 11-page self-administered mail questionnaire (see Appendix C) was used to collect data from active fishers including their demographic profile, fishing frequency, importance of fishing, motivations and reasons for participating, opinions and involvement in fisheries and marine park management, and the usefulness of public consultation techniques. Responses were measured on Likert-type scales. For instance, the level of participation in the rezoning implemented in 2004, and the opinion on whether government agencies should consult the public (including recreational fishers) about fisheries and marine park management decisions were measured as 'Yes' or 'No' type scale. Attitudes and perceptions questions elicited responses that indicates levels of importance (categories ranging from 1= not at all important to 5= extremely important, with statements about attributes of effective public consultation programs) and agreement (categories ranging from 1= strongly disagree to 5= strongly agree) with statements of why the public should be consulted. The level of usefulness was measured for techniques commonly used to inform and consult people about fisheries and marine park management issues (with categories 1= not at all useful, 2= moderately useful, 3= very useful, 4= don't know), and for different types of maps or mapping tools (with categories 1= no use, 2= little use, 3= moderate use, 4= a lot of use).

Processing and Analysis

Spatial data

The maps with the associated fishing locations for pre- and post-rezoning process were scanned, georectified, and entered into GIS for archiving and analysis. Fishing locations were then on-screen digitised using standard procedures of ArcGIS/ArcMap 9.2 (ESRI 2006) editing tools and the associated descriptive data (e.g. importance of fishing, reasons for fishing in the locations, target species, presence of submerged structures, fishing frequency, size area, distance from coast, and fishing compensation strategy) of each delineated spatial entity incorporated into a spatially geo-referenced attribute table. This allowed the information to be represented spatially in an electronic form, and lends itself to thematic and statistical analysis (Close & Hall, 2006; De Freitas & Tagliani, 2008).

A total of 690 current and 181 previous fishing locations were reported by recreational fishers in Townsville and Rockhampton. Prior to analysis and interpretation, the digitised spatial data were subjected to validation by the recreational fisheries during meetings of the Capricorn Reef Community-based Monitoring Program (CapReef) to check the veracity of the data.

Spatial analysis and mapping were conducted with ArcGIS - ArcMap™ 9.2. Data layers created and used in this study were standardized using the same projected coordinate system (Universal Transverse Mercator Zone 55S) and datum GDA 1994 (Geocentric Datum of Australia 1994) to minimize distortion of spatial properties in the study region and thus minimize spatial error in the analysis. The GIS tools *weighted sum* and *zonal statistics* were used to measure and document spatial changes in recreational fishing effort in the GBRMP.

To examine the changes in distances travelled, distances between the departure points (boat ramps) and the provided fishing locations were calculated through GIS *Spatial Analyst* (module *distance*). A total of 6 boat ramps point locations (identified by the symbology in the maps in Townsville (Lucinda, Townsville Coastguard, National Park/Ross River, Phillips Creek, Kierle’s Landing and Groper Creek) and 4 in Rockhampton (North, Yeppoon, Emu point and Battle Creek) were used as reference points to calculate travelled distances to the fishing grounds. The distances were measured from the boat ramps in relation to the centroid of each polygon (drawn area) or to underwater features (e.g. reef, shoal, rocks, banks, and islands) using the *Euclidean distance* within the *Spatial Analyst* tools. Distance values were extracted using *zonal statistics* analysis. The words ‘boat ramp (s)’ and ‘departure point(s)’ will be used interchangeably to refer to the coastal locations used by recreational fishers for the location of the beginning of their trip. Underwater features were characterized using a combination of spatial-based information and informal consultations with experienced recreational fishers. In most cases, the highest number of fishing location polygons were concentrated around and including underwater features visually identified in the zoning paper maps (scale 1:250 000) used in the interview process. However, structures smaller than 0.5 km in extent were not identified in the paper maps. In this case, digital hydrographic nautical charts from the Australian Hydrographic Office 2003 and GBR zoning layers from the GBRMPA 2003 were used. In addition, consultation with fishers provided supportive information on fishers' preference for marked structures such as reefs and rocks as good habitats for fish.

The average distance travelled before or after the rezoning by each fisher was calculated by summing all the distances from the boat ramp departure point on the coast to each location centroid divided by the total number of locations (Eq. 5.1). Differences between averaged distances were calculated to estimate the relative displacement in kilometers and percentages of travelled distances to the fishing grounds in relation to the previous fishing position (Eq. 5.2). Relative displacement was calculated for those fishers that provided information on both previous and current fishing locations. Positive and negative values indicate displacement further and closer, respectively, from the departure point on the coast in relation to the previous fishing position.

Eq. 5.1

$$A = \frac{\sum d}{n}$$

where *A* is the average of travelled distance for each fisher, *d* is the distance from the boat ramp departure point to the centroid of the fishing location an *n* is the number of fishing locations.

Eq. 5.2

$$R = \frac{A_c - A_p}{A_p} \times 100$$

where *R* is the relative displacement distance for each fisher, *A* is the average of travelled distance from the boat ramps to the centroid of the fishing location, *c* represents the current locations of current locations and *p* the previous (lost) locations. Positive and negative values indicate displacement further and closer, respectively, from the departure point on the coast in relation to the previous fishing position.

To measure changes in spatial distribution of fishing effort, an index of fishing pressure (Eq. 5.3) was calculated for current fishing areas through the weighted sum tool of spatial analyst module (ArcGIS - ArcMapTM 9.2). Vector polygons of previous and current fishing locations from each fisher were rasterized to a 30 m spatial resolution grid. The weighted sum function overlays several rasterized layers multiplying the cell values by a given weight (field value) and summing them together. The weight values were represented by the frequency categories (average of fishing boat trips per year) in which each fishing location was visited by recreational fishers (Table 5.1).

Eq. 5.3
$$FI(Rj) = \sum_{i=1} Nij * WRj$$

where FI is the fishing intensity index, Nij represents the number of fishing locations by fishers, and WRj is the frequency of visits (trips).

Table 5.1. Weight values for the input rasters.

Weight	Average Number Trips (last 12 months)
1	< 20
2	21 – 40
3	41 – 60
4	61 – 80
5	81 – 100
6	> 100

A random points' selection method was then used to attribute 10000 points to the spatial fishing intensity clusters. Values of fishing intensity, distance from submerged structures, and distances from the departure points located on the coast were then extracted using the Spatial Analyst tool – 'extract value to points'.

Normality of data used as dependent and independent samples was verified using a one sample Kolmogorov-Smirnov test. Because most of the data were not normally distributed, correlation between variables (e.g. distance to fishing locations, proximity to submerged structures, fishing frequency, area and number of fishing locations) was tested using the Spearman's rho non-parametric rank-order test. To examine relationships between these variables, Wilcoxon signed-rank tests were used for two related samples, Mann Whitney U tests were used for two independent samples, Kruskal-Wallis tests were used to compare three or more independent samples and Friedman tests were used to compare multiple dependent samples. For example, to measure differences in average distances travelled between previous and current, previous and new, and previous and location fishers fished more, the Wilcoxon test was applied. The Mann Whitney U test was used to analyse differences between spatial clusters of low and high fishing use. Kruskal-Wallis tests were used to compare fishers' opinions about the number, size and location with the average size of the fishing locations they provided. Friedman tests were used to analyse for differences between the level of approval of green zones and the size and number of fishing locations. The level of statistical significance was set at alpha = 0.05, and a Bonferroni correction (α= 0.05/n, where 'n' is the number of comparisons) was applied to analysis with multiple comparisons. All statistics analyses were conducted with SPSS version 15.0 for Windows with alpha = 0.05.

Non-spatial data

To evaluate recreational fishers' motivations to engage in the management of fisheries and the Marine Park, their perceptions towards the public participation process and the consultation techniques used, and usefulness of mapping information and spatial tools, questions were collected using Likert- type scales and analysed descriptively. Additionally, results were described separately for participants and non-participants in the consultation program to investigate differences in opinions and beliefs. Respondents were classified as 'participants' if they answered 'yes' to the question *'Did you attend a public meeting or make a submission to the Great Barrier Reef Marine Park Authority concerning the 2004 rezoning of the Great Barrier Reef?'*. Conversely, fishers who answered 'no' to this question were classified as 'non-participants'.

Data were tested for statistically significant differences between participants and non-participants using a Wilcoxon rank-sum test (Mann-Whiney U test) with alpha = 0.05. Reliability analysis was used to measure the internal consistency of multiple item scale questions. To aid interpretation, variables such as fishers' beliefs and opinions on effectiveness of public consultation process and techniques, and trust in the resource management agency, measured on 5-point response scales were collapsed into 3-point scales by combining the categories at each end of the scale (e.g., the 5-point agree-disagree scale was collapsed into categories "agree", "neutral", and "disagree" by combining agree with strongly agree and disagree with strongly disagree). For simplicity and to avoid repetition, the methodology and individual items used to assess and document observed spatial and related-social implications of the 2004 management changes of the GBRMP on recreational fishing activity and recreational fishers are described in the appropriate sections of the results.

In addition to the specific analysis described for spatial and non-spatial data, information from open-ended interview and survey questions were typed into a file as written with names of individuals removed to protect their confidentiality. Reponses to the open-ended questions were summarized by content analysis performed with the qualitative analysis software QSR NVivo V.7.0.247.0 SP2. Open-ended statements were coded independently by two coders achieving an inter-coder reliability score of 90%. These data and selected quotations are used in the results and discussion to provide support to the mail survey findings and to illustrate themes and patterns that emerged in the analysis.

5.3 Results

The results are presented in two sections. The first section asseses the potential of PPGIS tools (mapping-based information and GIS) in documenting and reflecting the implications of the observed spatial changes for recreational fishers (e.g. travel distances to fishing grounds, fishing frequency, target species) and for the Marine Park (e.g. concentration of fishing effort in remaining open areas, and the potential shift of fishing effort into previously under exploited areas).

The second section outlines the extent to which recreational fishers concerns were incorporated in the rezoning process. It also assess fishers' motivations and perceptions of public participation process and consultation techniques used in the management of fisheries and marine park-related issues including the usefulness of spatial data and geographic information tools in reflecting the effects of management changes in the allocation of recreational fishing effort within the GBRMP.

Spatial Changes in Recreational Fishing Effort and Distribution

The increase in no-take areas introduced by the 2004 rezoning of the GBR has substantially affected recreational fishing activity within the park. Major spatial implications are related to changes in fishers' access to marine resources, displacement of fishing effort and aggregation, and travel distances to fishing grounds. Information about fishing grounds was recorded on GBR zoning maps. A total of 871 fishing locations were identified by 132 fishers forming several distinct spatial clusters (Fig. 5.3).

From the 132 fishers, 76 fishers from Townsville characterised their pre- and post-rezoning fishing locations into 10 spatial clusters (Fig. 5.3). Overall, 449 fishing locations (representing 6 spatial clusters) were characterized as current fishing locations, and 133 locations (4 spatial clusters) were appointed by 66% as previous fishing locations. Fishers (n = 56) from Rockhampton reported a total of 289 fishing locations aggregated into 7 spatial clusters. From those, 241 locations (5 spatial clusters) were characterised as current, and 58 locations (2 spatial clusters) were identified by 50% of the fishers as previous fishing locations. It is important to note that the 50% who did not provide information on previous fishing locations can be attributed to two main factors: 1) they did not lose any fishing locations, or 2) they did not fish prior to the rezoning, and therefore no locations were previously lost.

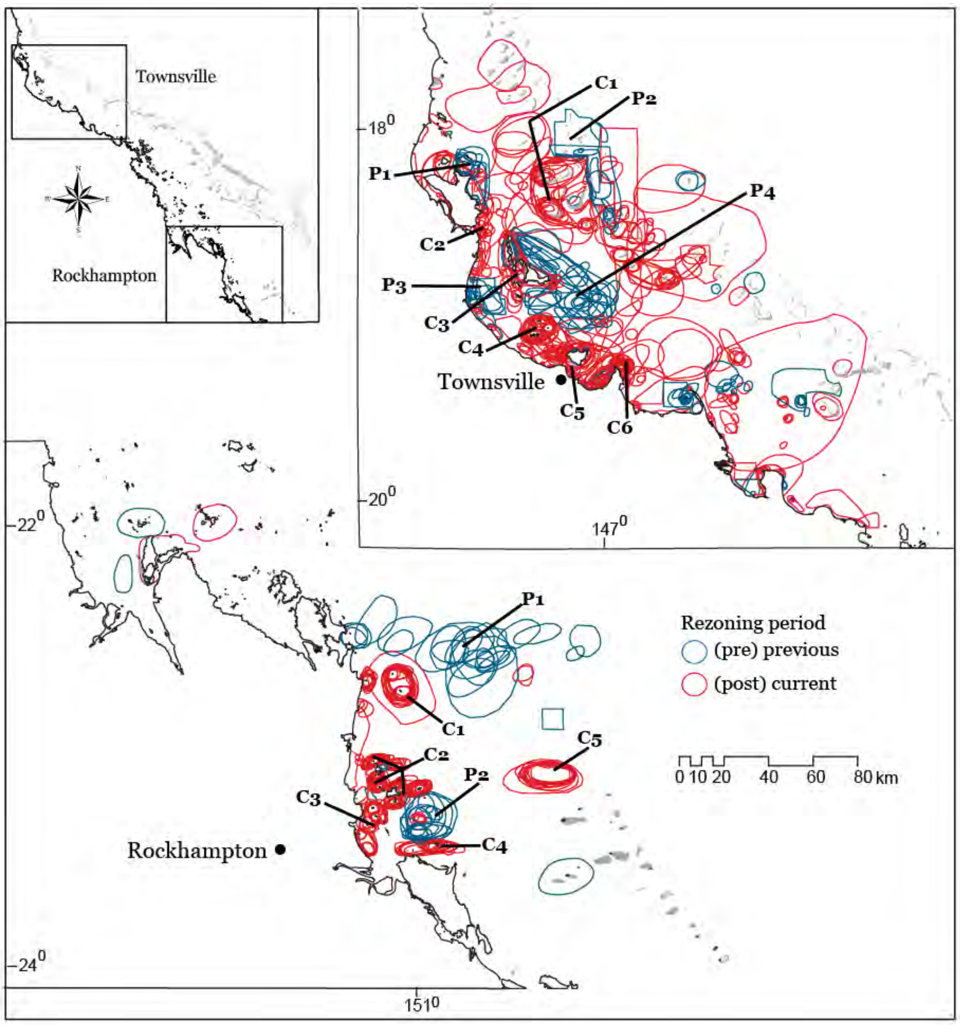

Figure 5.3. Polygons indicating location of previous (P) and current (C) fishing spots and number of spatial clusters.

To understand the degree of loss of fishing grounds frequented by recreational fishing, as well as the associated displacement of fishing effort, fishers were asked to mark on a paper rezoning map any locations/areas where they used to fish regularly but no longer can due to those areas being rezoned as “no-take” areas. Figure 5.4 shows the spatial overlay of 181 fishing locations reported as lost by recreational fishers.

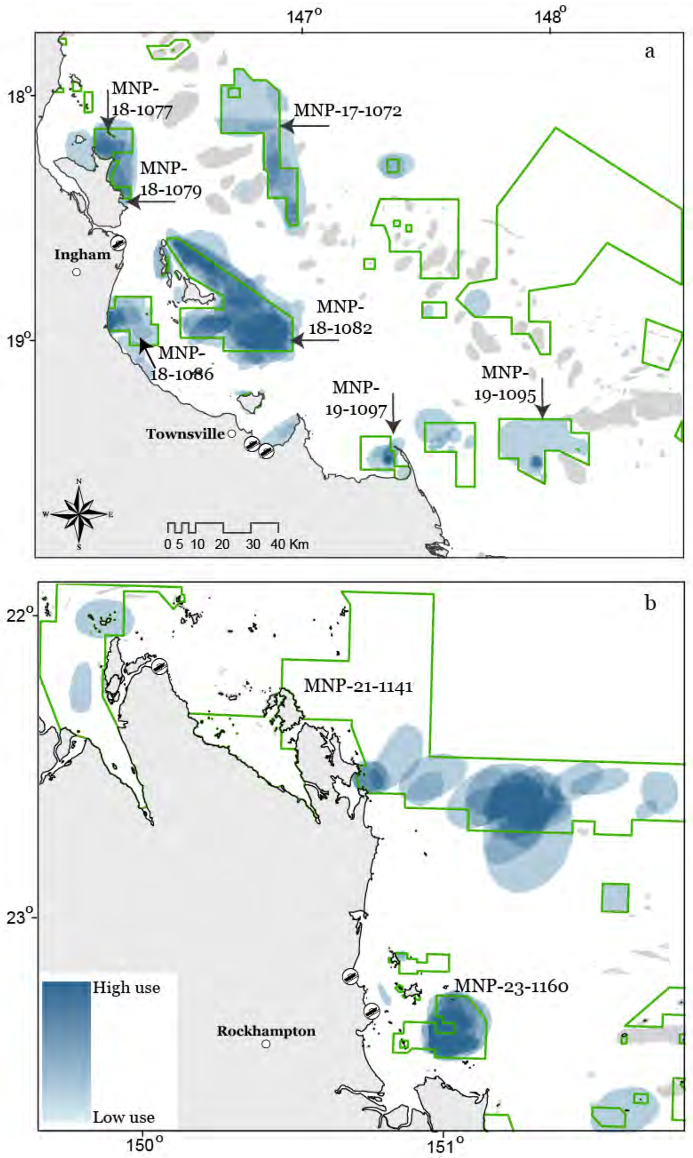

Figure 5.4. Spatial overlay of previous (lost) fishing spots in Townsville (a) and Rockhampton (b). MNP refers to Marine National Park (green zones or no-take areas).

Most fishers interviewed reported losing at least one of their regular fishing locations under the new Zoning Plan. Specific differences and patterns of fishing locations lost for both study sites are presented as follow.

In *Townsville*, 66% (n = 76) of fishers provided a total of 133 lost fishing locations (Fig. 5.3). On average, there was a loss of 3 previous fishing locations per recreational fisher. From those, 43% lost at least 1 regular fishing spot, 14% lost 2 locations, 12% lost 3 locations and 16% lost 4 locations. Fewer people (8%) lost 6 locations, and just 2% lost 5, 7 or 9 locations each.

Of those fishers who reported losses of previous fishing locations, the majority (42%) used to fish in 31 spots located at MNP-18-1082 (Fig. 5.4). The distance of the fishing locations to the closest boat ramps on the coast range from 24 to 55 km, with an average of 43 km (see Appendix C for a list of average distance values). Thirty percent of the fishers used to fish in 17 fishing location at MNP-18-1086, with fishing distances ranging from 28 to 41 km from the nearest boat ramp. The MNP-19-1097 used to provide 14 fishing spots for 24% of the respondents, with fishing distances from the nearest boat ramp located at 40 Km. Other fishers fished in 12 spots, previously located at the MNP-18-1077 and MNP-18-1079, distant at 35 km from the shoreline boat tramps.

In *Rockhampton,* 48 previous fishing locations were provided by 28 fishers (Fig. 5.3). On average, there was a loss of 2 (43% of respondents) previous fishing locations. From those, 39% lost at least 1 regular fishing location, 14% lost 3 locations, and 4% lost 4 locations. Of those fishers who reported loss of previous fishing locations, 39% used to fish in 14 spots located at MNP-23-1160, including Lisa Jane Shoals and Jabiru Shoals (see Appendix C for a list of average distance values). The distance of the fishing locations to the coast ranged from 25 to 32 km, with an average of 29 km Thirty six percent of the fishers used to fish in 20 fishing locations in the current MNP-21-1141, with fishing distances ranging from 77 to 135 km (mean = 93.14).

Fishing Compensation Strategies

To understand the rezoning implications for recreational fishing, fishers were asked to mark on paper maps how they compensated for or adjusted to the loss of fishing areas. Results indicated that to compensate for the loss in fishing grounds, affected individuals either fish more in 113 (81 in Townsville and 32 in Rockhampton) of their previous locations that still remain open or have shifted their fishing activity to 38 (25 in Townsville and 13 in Rockhampton) substitute (and in many cases areas they had not fished before) areas within the Marine Park. Fishing effort displaced from the new no-fishing zones tended to move inshore by approximately 27% and to areas already heavily used by recreational fishers. Overall, only 3 out of 76 fishers reported that they have also compensated for the loss of areas by going fishing, on average, 2 times more they usually did before the rezoning.

Fishing more at current locations

Recreational fishers have compensated for the loss of fishing locations due to the rezoning by fishing more at their other fishing locations that still remain open to fishing. A total of 113 locations were provided by fishers from both study sites (Fig. 5.5). From those, 81 were identified in the Townsville region and 32 in Rockhampton.

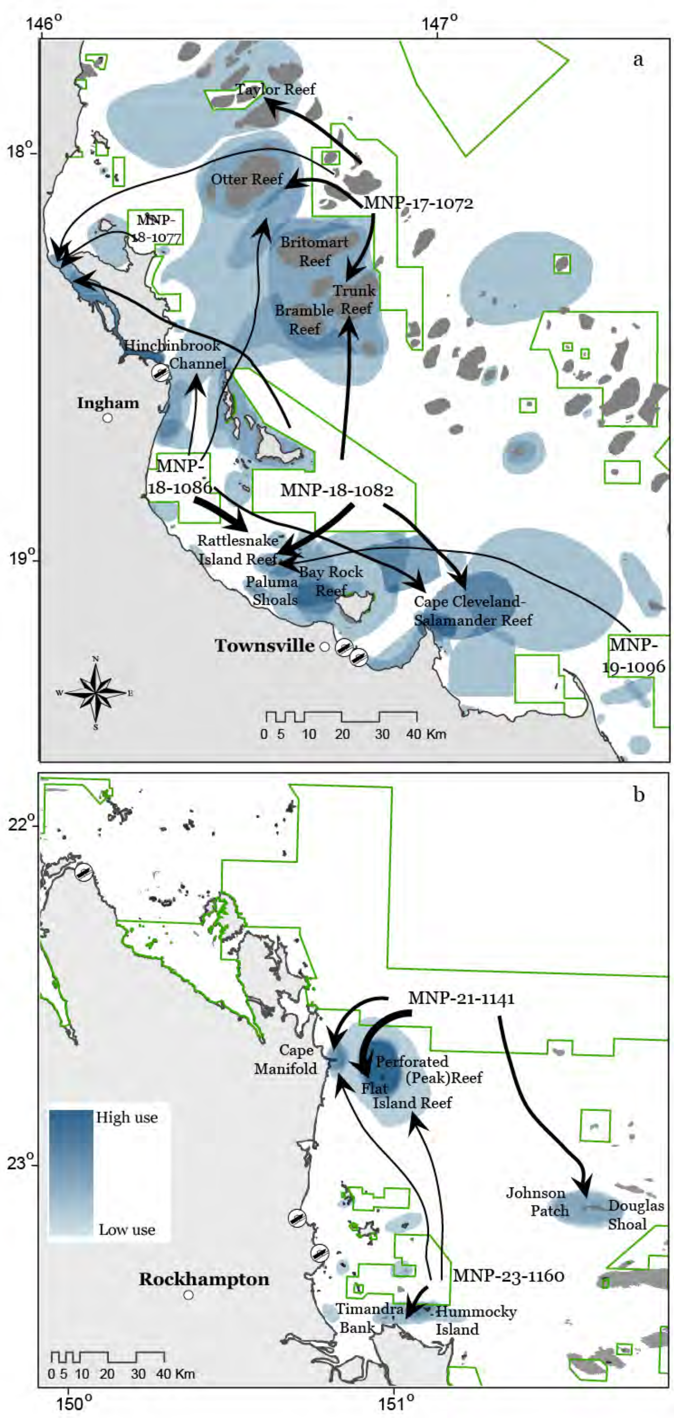

Figure 5.5. Schematic representation of spatial displacement from lost previous locations to fished more locations in the Townsville (a) and Rockhampton (b) regions. MNP refers to Marine National Park (green zones or no-take areas). Thickness of arrows represents frequency of fishers' displaced.

Overall, the majority of fishers (Townsville: 52%, n = 76, Rockhampton: 57%, n = 56) reported that they compensated for the loss of areas by fishing more in at least 1 current fishing location.

In *Townsville,* the inshore regions of Salamander Reef – Cape Cleveland and the region between Rattlesnake Island and Magnetic Island, including for instance Bramble Rock, Lorne Reef, Burdekin Reef, and Paluma Shoals were preferred by 17% (n = 35) of the fishers each (Fig. 5.5a). The average distance from the departure boat ramps to those locations varied from 23 Km (Salamander Reef – Cape Cleveland) to 27 km (Rattlesnake Island and Magnetic Island). The Hinchinbrook Channel (mean = 30 km) and the nearshore reef region (mean = 27 km) of Taylor Reef, Otter Reef, Britomart Reef and Bramble Reef are also locations where 14% of fishers in each region reported fishing more. The majority of fishers used to fish in the MNP-18-1082 (50%) and MNP-18-1086 (35%). In those MNP zones, previous fishing locations were distant, on average, at 43 km and 37 km from the departure points on the coast, respectively. Other locations identified by 38% of fishers have not presented a clustered pattern, and these locations tended to be sparsely located around Great Palm Island and coastal catchments from Cape Cleveland to the town of Bowen (located at the southern portion of the study area).

In *Rockhampton,* of those fishers (n = 21) who reported that they compensated for these lost locations by fishing at other locations, 52% preferred Perforated (Peak) Reef and Flat Island Reef (59 km from the boat ramps), followed by 24% who fish more in Timandra Bank (including Keppel Rocks) and Hummocky Island (including Hummocky Reef, Fairway Rock Reef, and Ship Rock Reef) region (distant 36.89 km), and 19% fish more in Cape Manifold (distant 54.66 km) (Fig. 5.5b). The majority of fishers (57%) who provided information on locations they fish more after the rezoning used to fish in the MNP-21-1141, and 43% in the MNP-23-1160. In those MNP zones, previous fishing locations were distant, on average, at 93 and 29 km from the nearest boat ramp respectively. Other locations people reported fishing more include Johnson Patch and Douglas Shoal (14%), on average 90 km from the boat ramps, and Lisa Jane Shoals, 26 km from the departure ramps on the coast.[12]

[12] Total % sum exceeds 100% because fishers could report more than 1 location in each or amongst the 4 locations provided.

Fishing at new locations

Many fishers who reported they have lost fishing locations due to the rezoning reported that they have also compensated for loss of these areas by fishing at previously less exploited locations. In total, 38 new fishing locations were provided by fishers from both study sites (Fig. 5.6). From those, 25 new fishing locations were identified in the Townsville region and 13 in Rockhampton.

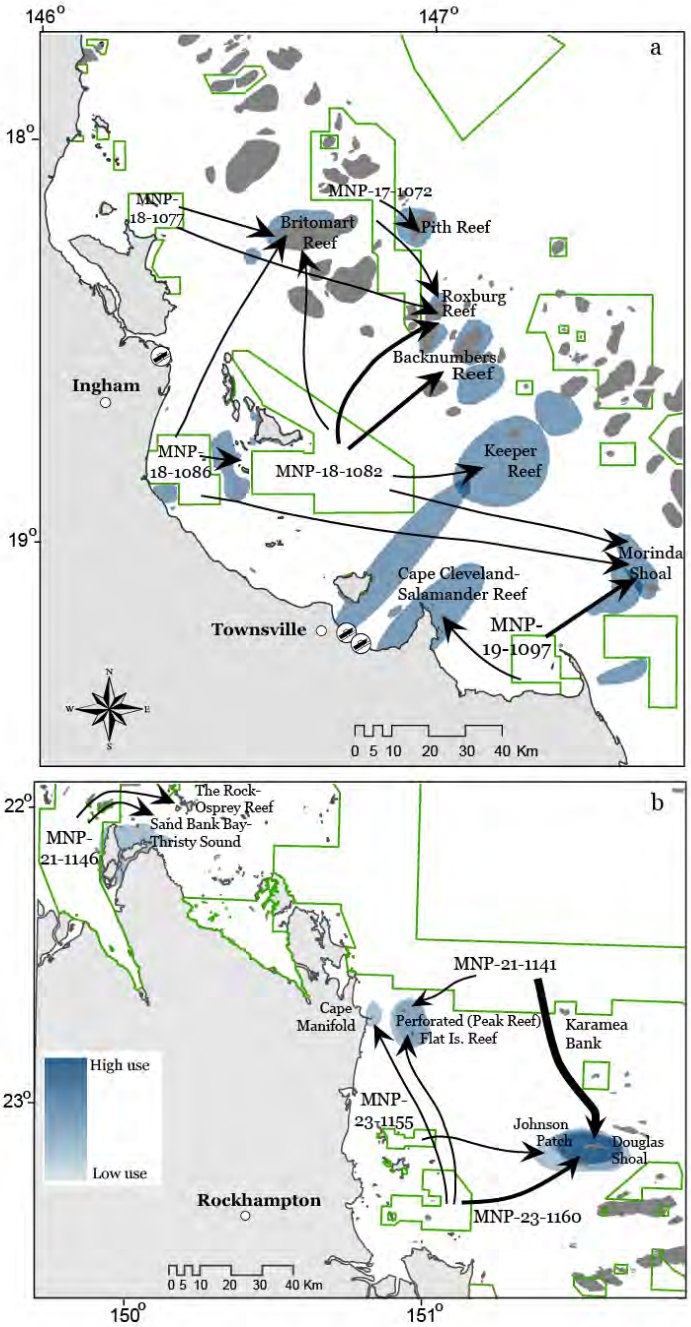

Figure 5.6. Schematic representation of spatial displacement from lost previous locations to new fishing locations in the Townsville (a) and Rockhampton (b) regions. MNP refers to Marine National Park (green zones or no-take areas). Thickness of arrows represents frequency of fishers' displaced.

Overall, most fishers (Townsville: 26%, n = 50, Rockhampton: 21%, n = 56) reported they compensated for the loss of areas by fishing more in at least 1 new fishing location. Distances from the boat ramps to the new fishing locations ranged from 14 to 87 km (mean = 48 km) and 13.31 to 91.21 km (mean = 78 km) in Townsville and Rockhampton, respectively (see Appendices 5.2-a and –b for a list of average distance values).

In *Townsville*, the region covered by Britomart Reef, Roxburg Reef, Backnumbers Reef and Keeper Reefs, on average 72 km from the boat ramps, represents new fishing locations for the other 46% fishers (n = 13) (see Appendix C). Of those, 67% used to fish in the MNP-18-1082, and a minority of fishers (33%) reported they used to fish in MNP-18-1086, MNP-18-1077 and MNP-18-1079 (Fig. 5.6a). Thirty one percent identified the nearshore areas of Salamander Reef and Great Palm Island Reef, with distances ranging from 14 to 37 km from the boat ramps. Most of these fishers (50%) used to fish previously on MNP-18-1086, one respondent fished MNP-18-1082, and the other fished MNP-18-1077 and MNP-18-1079. Finally, a minority of fishers (15%), also identified Morinda Shoals, located at 52 km from the boat ramps, as a new fishing location. From those, most fishers (50%) used to previously fish at MNP-19-1097.

In *Rockhampton,* most fishers (75%, n = 12) identified Johnson Patch and Douglas Shoals as a new fishing location, with distances ranging from 87 to 91 km from the departure points (see Appendix C). Most of these fishers used to fish previously in MNP-21-1141 with fishing locations distant, on average, at 93 Km from the departure points. Perforated Island and Flat Island was the second new fishing area (on average 58.6 km from the nearest boat ramp) reported by the 18% of fishers (Fig. 5.6b). Of those, 25% used to fished in the MNP-23-1160, and a minority (17%) reported they used to fish in MNP-21-1146, and MNP-23-1155. Therefore, fishers who used to fish in the MNP-23-1160 (with fishing locations distant on average at 29 km from the departure boat ramps) tended to move their fishing effort to both Johnson Patch and Douglas Shoals and Perforated Island and Flat Island, located at 87 km and 59 km from the nearest boat ramp, respectively. One respondent who used to fish in two spatially distant MNP areas (MNP-23-1160 and MNP-23-1166, 29 km and 103 km from the boat ramps, respectively) also chose Perforated Island and Flat Island (58 km) as new fishing location. The other MNP chosen by only one fisher as previous fishing area was the MNP-21-1146 (31 km from coast) located in the north part of the studied region, and in this case its new location (Sand Bank Bay-Thirsty Sound, 24 km from the nearest boat ramp) tended to be close to the previous one.

Fishing Intensity Index

The previous section demonstrates that most recreational fishers lost at least 1 regular fishing location due the rezoning process. To compensate for such loss, fishers have adopted three main compensation strategies: i) fish more in their other favorite locations that remain open, ii) select previously less exploited areas, and iii) increase fishing frequency.

To assess the extent to which management changes in the rezoning of the marine protected areas in the GBR has affected recreational fishing, fishers were asked to mark on the map their most important saltwater fishing locations within the GBR. The combined results of fishing compensation strategies and regular fishing locations that are still open to fishing reflect where and to what extent fishing effort has been displaced. As mentioned previously, a total number of 690 locations (449 from Townsville and 241 from Rockhampton) were recorded in the GBR zoning maps as current fishing spots (see Fig. 5.3).

To investigate how recreational fishing effort is distributed within the GBR study sites, fishing locations were overlaid and weighted based on fishers' number of locations and fishing frequency (see Eq. 5.3 and Box. 5.1). The maps derived from the weighted sum spatial analysis represent a grid-based (30×30m) continuous surface (raster) layer in which each pixel indicates the fishing intensity value in a particular location (Figs. 5.7a and b). The fishing intensity index is represented by composite-range of red colours indicating high to low use of fishing grounds by recreational fishers. The darker the red, the more concentrated (higher intensity) is the fishing activity in that location.

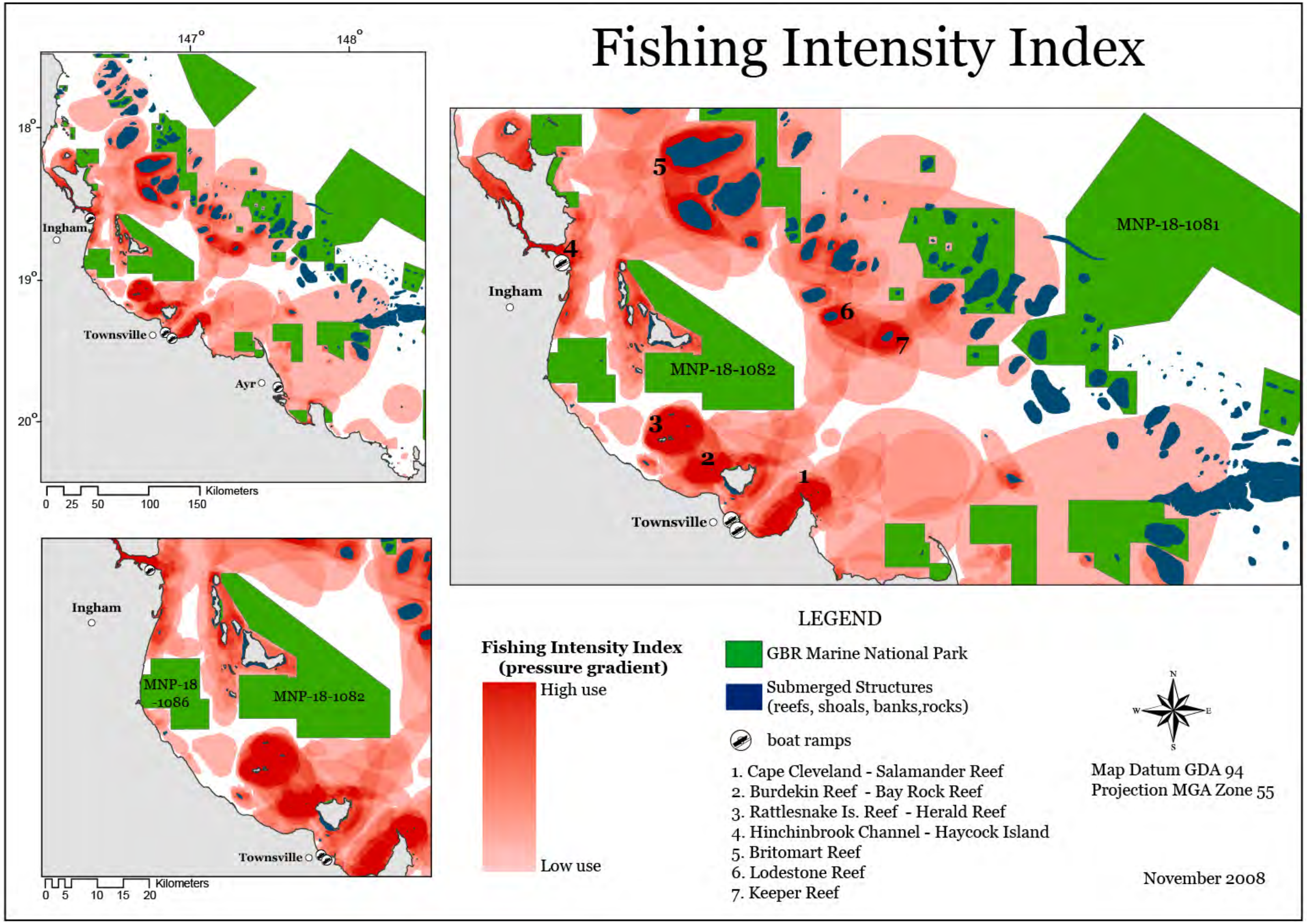

Figure 5.7a. Fishing intensity map of the most important saltwater recreational fishing locations within the GBR for the Townsville site.

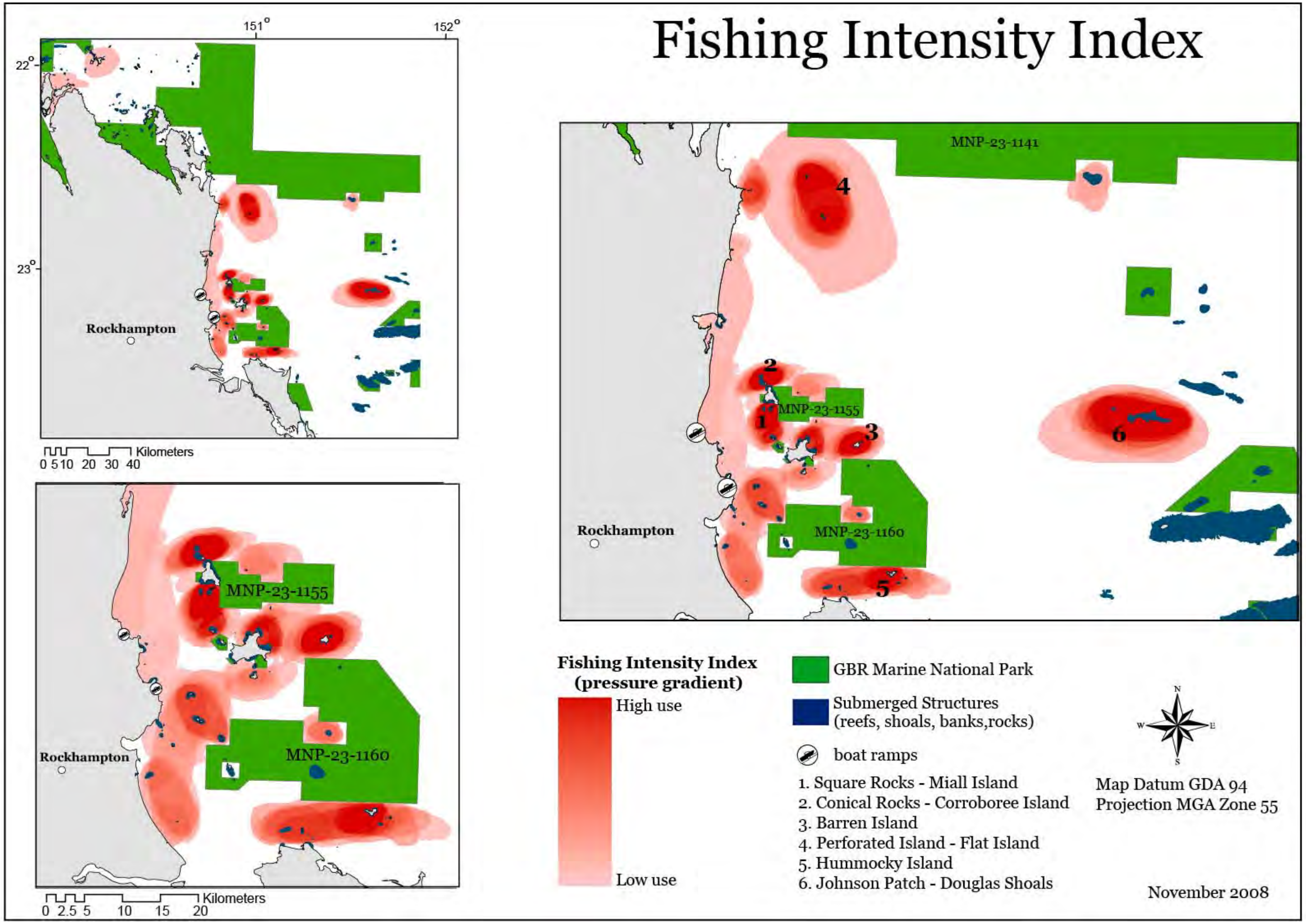

Figure 5.7b. Fishing intensity map of the most important saltwater recreational fishing locations within the GBR for the Rockhampton site.

The spatial index for fishing intensity shows that most of the high use areas are allocated to locations close to the coast or nearshore areas and are concentrated around the borders of submerged structures, particularly reefs, shoals and banks. However, the two study sites present distinct spatial patterns of fishing intensity distribution, with a more dispersed distribution structure in Townsville (Fig. 5.7a), and a more aggregated (clustered) pattern in Rockhampton (Fig. 5.7b). Independently of the spatial structure pattern (dispersed or aggregated), the presence of discrete groups (or clusters) of high fishing intensity use is noticeable. Clusters of fishing intensity, previously characterised in section 5.3.1, have been refined by the weighted overlay analysis. The spatial intensity index maps shows 7 clusters of high use for recreational fishing in Townsville (Fig. 5.7a) and 6 in Rockhampton (Fig. 5.7b).

In *Townsville*, fishers currently fish, on average, at 6 fishing locations (449 locations, 76 respondents) with a fairly even distribution of numbers of current sites across the respondents. Most fishers currently fish in 3 (15%), 4 (11%), 5 (16%), 6 (13%) and 8 (11%) locations. Fourteen percent fish in less than 2 locations, and a total of 20% fish in 9 or more locations. The number of current fishing locations decreased with the distance from the departure points with 43 fishing locations reported in the Salamander Reef and round Cape Cleveland, located on average at 21km and a small number of locations (n = 11) located at 41Km from the nearest boat ramp (see Appendix C). Areas marked as most important for fishing include: i) Cape Cleveland-Salamander Reef , including Four Foot Reef and Twenty Foot Reef, chosen by 37% of fishers (mean = 21.03 km ii) Burdekin Reef and Bay Rock Reef (mean = 18.20 km) was the preferred area for 32%, iii) Rattlesnake Reef and Herald Reef (mean = 25.29 km) by 24%, and iv) and Britomart Reef (mean = 50.35 km) by 14 % respondents) [13] (Fig. 5.7a).

In *Rockhampton*, of the 241 current fishing locations provided (n = 56), 26% fishers reported they currently fish, on average, at 4 regular fishing spots. Twenty percent of fishers have 2 fishing locations, 9% fish in 3 locations, other 20% fish in 5 locations and 11% in 7 locations. Less than 2% reported they fish in just 1 location, and 10% fish in 8 or more locations. The number of current fishing locations decreased with the distance from the departure point with 35 fishing locations reported in Square Rocks and Miall Island located 15 km from the nearest boat ramp, and a small number of locations (n = 20) are at least 28 km from the boast ramps (see Appendix C). Most important fishing areas include: i) Square Rocks and Miall Island region, chosen by 54% (mean = 15.27 km), ii) Conical Rocks and Corroboree Island (mean = 18.01 km), was the preferred area for 50%, iii) Barren Island (mean = 28.35 km), including Barren

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[13] Total % sum exceeds 100% because a same recfishers can have more than 1 location in each or amongst the 4 locations provided.

Reef and the Child Reef, by 36%, and iv) Perforated Island and Flat Island (mean = 58.31 km), by 27% (Fig. 5.7b).

In both study sites, the number of current fishing locations decreased with the distance from the departure points (see Appendices 5.2-a and -b for descriptive statistics). Overall, the highest intensity use locations are located at less than 30 km from the nearest boat ramp (see Appendix C for descriptive statistics). Further away from the coast, locations of highest use are located at 62 km from the nearest departure point, on average.

Data from open-ended interview questions revealed that locations closer to the coast, and those away from the coast, were chosen for very different reasons. Locations closer to the coast were chosen by 50% of the fishers because of their accessibility (travel distance and travel time) and proximity to home and boat ramps. Other reasons included shelter/safety, target for specific species (15%), productive areas/good fishing (10%), and other (e.g. leisure activities such as be with friends, boat and relaxing, and fishing competitions). High intensity use fishing grounds located more distant from fishers' departure points were mainly chosen due the quality of fishing (productive areas) (40%), accessibility and proximity (to Townsville), less crowed (15%), alternative fishing spots (15%), and other (e.g. scenic view, scuba dive) (10%).

To analyse if high use fishing spots were correlated with proximity to the boat ramp departure points and submerged structures, the non-parametric statistical test Spearman's rho was applied. Overall, a negative relationship was found between the mean values of relative fishing intensity and distance from the departure point for the spatial clusters of high fishing use, suggesting that high intensity use locations are at shortest distances from the boat ramps. However, this correlation was not found significant (Spearman's rho non-parametric test, $r(4) = -0.80$, $p = 0.20$) for the Townsville data, suggesting no effect between the mean values of relative fishing intensity and distance from the nearest boat ramps for the major spatial clusters of high fishing use (Fig. 5.8a). Conversely, Rockhampton data shows a significant negative correlation (Spearman's rho non-parametric test, $r(6) = -0.886$, $p = 0.019$) between the mean values of relative fishing intensity and distance from the nearest boat ramps for six spatial clusters of high fishing use, indicating that the closest to the coast, the highest the fishing intensity (Fig. 5.8b).

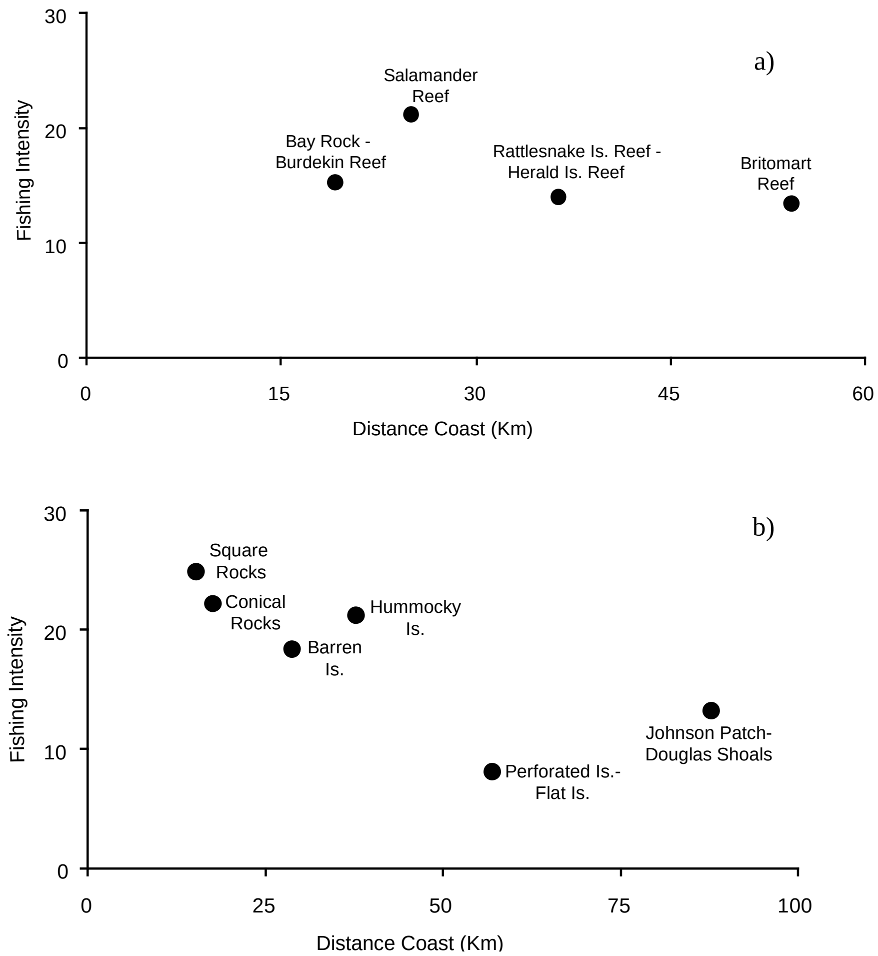

Figure 5.8. Average fishing intensity and distance (km) from the boat ramp departure points to spatial fishing clusters in Townsville (a) and Rockhampton (b).

Additionally, results of Spearman's rho non-parametric test indicate that the relative fishing intensity index is negatively correlated ($p = 0.001$) with the distance of submerged structures (Fig. 5.9).

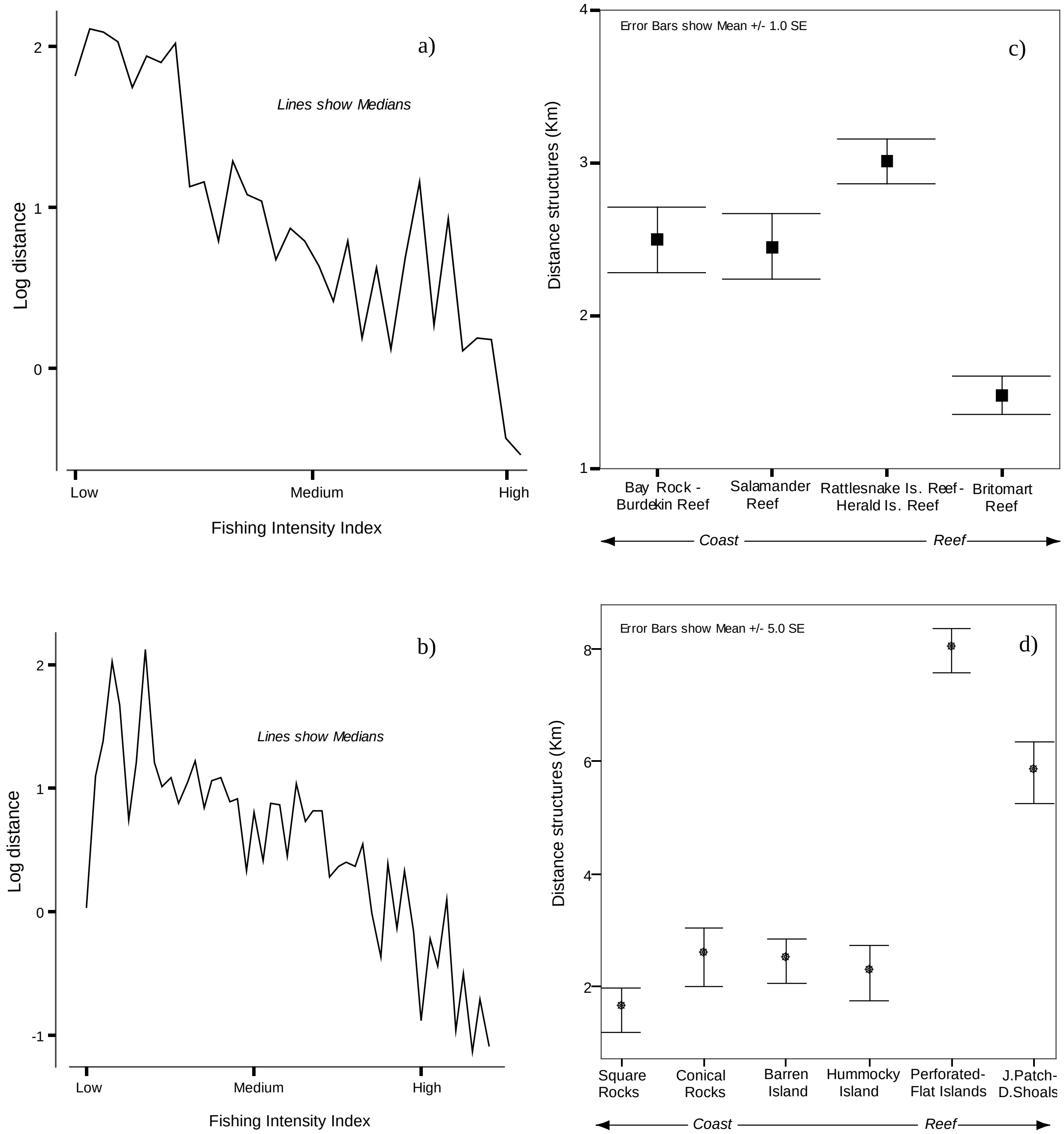

Figure 5.9. Fishing intensity and average distance (logarithmic scale) from submerged structures in general ((a) Townsville, (b) Rockhampton) and for the different high intensity fishing spots ((c) Townsville, (d) Rockhampton).

Significant differences between spatial clusters of low and high fishing use in Townsville (Mann Whitney U test, $z = -10.56$, $p = 0.001$) and Rockhampton (Mann Whitney U test, $z = -9.28$, $p = 0.001$) indicate that high fishing intensity values are concentrated on average at 2.1 km and 1.9 km, respectively, from the underwater features. Low fishing intensity gradients are located, on average, at 8.3 km in Townsville and 5.6 km in Rockhampton.

Spatial Displacement of Fishing Effort

To measure the extent to which management changes in the rezoning have affected recreational fishing distribution, differences (Eq. 5.2) in travelled distances from the boat ramps to the fishing grounds were calculated for those fishers that provided information on both previous and current fishing locations. Sixty six percent (n = 76) of fishers from Townsville and 50% (n = 56) of fishers from Rockhampton provided information on both pre- and post-fishing locations (see Fig. 5.3 and Appendix C for a list of average distance values).

Results show a mixture of movement further away and closer to the fishing departure points but, overall, spatial data on average distances indicates that, since rezoning, most fishers tended to displace their fishing effort towards inshore areas (Wilcoxon T-test z = -2.66, p = 0.008). Differences in number, size and location of no-take zones within the study sites might have influenced how fishing effort was displaced throughout available fishing grounds. The details for spatial displacement of fishing effort specific of Townsville and Rockhampton region are expanded on the following paragraphs.

In *Townsville*, from the 66% (n = 76) who provided information on pre- and post-fishing locations, 54% reported a displacement of 28% (with distances ranging from 1 to 38 km, mean = 13 km), on average, closer to their departure points in relation to their previous fishing locations. Conversely, the remaining 46% indicated that, on average, they go 47% more distant than they used to go before the rezoning process, with distances ranging from 0.19 to 51km (mean = 13.20; median = 10.39).

Regarding fishing compensation strategies, 46% (n = 76) of fishers compensated for the loss of areas by fishing more in other areas they used to fish before the rezoning. From those, 59% fish more in locations situated, on average, 37% closer to the departure point (with distances ranging from 2.16 to 38.20km, mean = 14.92). The other 41% of fishers fish more at locations situated on average 36% more distant from their departure points with distances ranging from 0.83 to 51.38km (mean = 12.44; median = 10.24). Fishing at new locations was also reported as a fishing compensation strategy by 17% (n = 76) of fishers. From those, a minority (23%) reported that, on average, their new fishing locations are 22% closer to coastal areas, with distances ranging from 3 to 23km (median = 9.61, S.E. mean = 6.56 , SD = 11.36). The majority (77%) indicated that their new fishing locations are situated on average 42% more distant from their departure points compared to their previous locations, with distances ranging from 1 to 57 km (median = 11.33, S.E. mean = 5.68, SD = 17.96).

Overall, no significant differences were observed between the average distances of current (Wilcoxon T-test z = -0.67, p = 0.50), new (Wilcoxon T-test z = -1.78, p = 0.07), and fishing more (Wilcoxon T-test z = -1.20, p = 0.23), locations in relation to their previous fishing locations.

In *Rockhampton*, only 50% (n = 56) of fishers provided data on both pre- and post- fishing locations. From those, the majority (78%) fished on average 32% (with distances ranging from 0.57 to 51.94 km, mean = 18.44 km) closer to their departure points in relation to their previous fishing locations. The other 22% indicated that, on average, they travel 43% further than they used to go before the rezoning process, with distances ranging from 1.84 to 34.36 km (mean = 9.93km; median = 4.22).

As for fishing compensation strategies, 37% (n = 56) of fishers reported fishing more in areas they used to fish before the rezoning. From those, the vast majority (81%) reported fishing at locations 34% closer (distances ranging from 1 to 42.29 km, mean= 20.21 km) to the coast in comparison with their previous locations, on average. The other 19% reported that the locations where they fish more locations are situated, on average, 21% more distant with distances ranging from 2.78 to 9.90 km (mean = 6.11; median = 5.88). Fishers (21%, n = 56) also compensate for the loss of locations by fishing in new locations in where they did not previously fish before the rezoning. Of these, 45 % fish in new locations that are on average 22% closer than their previous locations, with distances ranging from 3.81 to 18.78 km (mean = 13.68; median = 17.03). However, most fishers (55%) indicated that their new fishing locations are situated on average 50% further away from the departure points compared to their previous locations, with distances ranging from 2.26 to 60.24 km (mean =16.81; median = 9.41).

Compared to the average distances to previous locations, there were significant differences between the average distances of fishers' current locations (Wilcoxon T-test z = -3.415 p = 0.000) and the locations they report fishing more since the rezoning (Wilcoxon T-test z = -3.458 p = 0.000) in relation to the average distances of previous locations. A small but still significant difference was also found between the average distance of new and location they fish more (Wilcoxon T-test z = -2.366 p = 0.0017). No significant difference (Wilcoxon T-test z = -0.267, p = 0.790) was found between the average distance of new and previous fishing locations. These results indicate fishers' preference for coastal locations when they have to compensate for the loss of locations due to the rezoning. It also suggests that when looking for new locations, fishers prefer locations that are closer to their previous locations, which used to be more distant from coastal (inshore) locations.

Other Spatial-related Results

Other reported changes related to the displacement of recreational fishing effort in response to the management changes of the 2004 rezoning included: changes in frequency, substitution of species targeted, and differences in the level of approval of green zones (no-take areas) in relation to the size of the fishing location that fishers reported. Each of these is discussed in the sections below.

Changes in Fishing Frequency

The observed spatial changes in fishing displacement also affected the frequency with which fishers went fishing. Data of open-ended interview questions revealed that the most commonly cited reasons influencing frequency and satisfaction with recreational fishing were increased fishing costs (mainly in regarding to fuel and equipment), reduced fishing quality, restricted access to areas considered to be of 'high quality' for recreational fishing and increased crowding in areas that remain open.

Implications for fishing frequency were analysed for those fishers (n = 77) who reported both current and previous locations and fishing frequencies. Overall, the vast majority of fishers (74%, n = 77) fished between 1 and 20 times in the previous 12 months, and just 4% reported more than 60 fishing trips. Overall, results indicate that, independently of fishing frequency category, current fishing locations tended to be closer to the departure points compared to pre-rezoning locations (Wilcoxon T-test z = -2.66, p = 0.008) (Fig. 5.10).

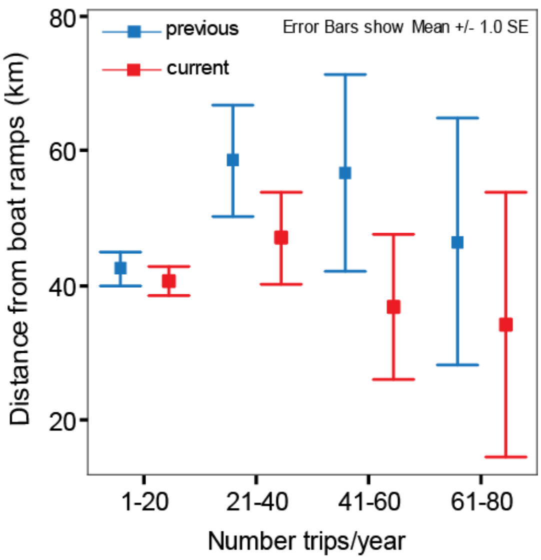

Figure 5.10. Fishing frequency (number of fishing boat trips in the last 12 months) for pre- and post-rezoning process.

Prior to the rezoning, fishers who fished less then 20 times per year reported fishing an average of 43 km from the nearest departure point. Fishers fishing between 21-40 times used to fish on average at 58 km, and those fishing between 41-60 times reported an average distance of 56 km. Fishers who went fishing 61 times or more in the last 12 months reported fishing an average of 47 km from their departure point. After the rezoning, frequency data shows that fishers traveling between 1 and 20 times reported fishing distances ranging from 13 to 87 km (mean = 40.70) while those who fish between 21-40 times fish on average at 47 km from the nearest departure point (Fig. 5.10). Fishers who go fishing more frequently, 41-60 and 61-80 times per year or more, tend to fish closer to their departure points with average fishing distances of 37 and 34 km, respectively.

However, despite an initial assumption that fishers who fish more often would fish at closer distances to the departure points and those with small number of trips per year would travel to further distances, no significant difference (Friedman test, χ^2 (3, N = 78) = 4.20, p = 0.24) was found between fishing frequency and the mean distance from the boat ramp departure points for combined previous and current categories of fishing frequency.

Substitution of Targeted Species

Spatial displacement of fishing effort by distance travelled towards inshore areas of 28% on average in Townsville and 32% in Rockhampton may also have implications for both fishers (changes in the species most targeted by fishers) and for fisheries management (shift fishing pressure to some species which will become more vulnerable to exploitation). Fishers were asked if the loss of fishing grounds has caused them to change their target species. Of the 29% who changed their target species after the rezoning, the majority switched to creek, estuarine and inshore species. Seventy one percent (n = 132) of fishers reported either no changes in the targeted species or did not answer the question.

The results show that spatial changes in the GBR have affected to some extent what species people target. The change in targeted species expressed by 29% of fishers is consistent with the displacement of effort towards inshore and non-reef areas. Data from open-ended interview questions indicated the most reported species identified by fishers who reported changing to nearshore-offshore species were Mangrove jack, Barramundi, and Fingermark. Nannygai, Coral Trout, Emporer, and Spanish Mackerel.

Differences in the level of approval of green zones and provision of spatial information

Anecdotal research on cognitive spatial knowledge suggests that people’s construction and translation of geographic-related information is influenced by how they perceive and interact with their context (Close and Hall, 2006, Prigent *et al.*, 2008). Fishers were asked to rate their level of approval (on a 5 point scale were 1= strongly approve and 5= strongly disapprove) with the size, number, and location of green zones in the areas where they fish. To assess whether fishers’ support of the rezoning and level of approval with number, size and location of green zones are reflected by the way they provided spatial information on fishing locations, statistical analysis were performed. The initial assumption was that fishers who disapprove of the green zones, those who lost more locations, and those with fewer current locations would try to avoid the identification of their specific spots by providing larger areas.

Fishers’ opinions on the level of approval of the green zones were analysed in relation to the average size of the fishing locations they provided. The highest level of approval (38.2%, n=132) was reported for the number of green zones, whereas the highest level of disapproval was attributed to the location (40.5%) followed by the size (37.2%) of the green zones. Overall, no significant difference exists on the attitudes towards support of the rezoning process and the average size of provided fishing locations (Kruskal-Wallis test, $\chi^2 = 1.40$, df = 2, p = 0.50). However, of the three variables (number, size and location) analysed for the level of approval of green zones, significant differences exist in relation to the fishers’ level of approval to the location ($\chi^2 = 9.51$, df = 2, p = 0.01) of green zones and the size of the fishing locations fishers provided (see Appendix C for descriptive statistics).

Those who disapprove of locations of green zones reported fishing locations 45% larger in size than those who were not affected by the rezoning (Mann Whitney U test, z = -2.44, p = 0.01). There was no significant effect of fishers’ support for the size (Kruskal-Wallis test, $\chi^2 = 7.51$, df = 2, p = 0.02) and number ($\chi^2 = 5.28$, df = 2, p = 0.07) of green zones on the average area of fishing locations provided.

Further analysis was conducted to test for differences in the number of locations provided by fishers and the average size of the fishing locations they drew on the paper maps. When data from Townsville and Rockhampton were analysed together, no significant difference between the mean area of previous (Friedman test, χ^2 (5, N = 71) = 3.742, p = 0.587) and current (χ^2 (14, N = 122) = 15.964, p = 0.316) fishing locations in relation to the size of the fishing locations (see Appendix C for descriptive statistics). However, when data from Townsville and

Rockhampton were analysed separately, a significant difference (χ^2 (8, N = 54) = 19.35, p = 0.01) was found between the average size of the fishing locations and the number of current locations for the Rockhampton region (see Appendix C for descriptive statistics). The mean area of current fishing locations is negatively correlated with the number of current fishing locations (Spearman's rho test, r (54) = -.422, p = 0.01). Fishers from the Rockhampton region with 1 (1.9%), 2 (21%), and 3 (9%) current fishing locations reported fishing areas larger in size (Mann Whitney U test, z = -3.92, p = 0.001) than those fishers with 4 (26%) and 5 or more locations (22%). Fishers with up to three current fishing locations provide areas 70% larger (mean = 134.58) in size than do those with four or more locations (mean = 39.21)

Overall, fishers who disapproved of the location of green zones and those fishers in Rockhampton with 3 or less current locations reported fishing areas larger in size that other fishers. This result suggests that contextual factors associated to changes in management plans that directly affect fishers' interaction with fishing might have some influence on the information they provide. In this particular case, fishers might have provided areas larger then the average as a way to prevent their specific fishing locations to be identified and, potentially, be turned into no-take areas. Perceptions, concerns and motivations of recreational fishers regarding public consultation and consultation techniques are detailed in the next section.

Social Assessment of Fishers' Perceptions of Public Participation Process and Consultation Techniques

To provide improved understanding of how fishers can be better engaged in the management process, fishers who completed the mail survey were asked a series of questions about their motivations, attitudes and beliefs regarding public consultation and specific consultation techniques. Previous research conducted by Sutton (2006a,b) suggested that only a minority of recreational fishers participate in public consultation programs and that these fishers may not be representative of the wider recreational fisher population in Queensland (Sutton 2006a,b), To verify the results of Sutton (2006a,b) and to provide further insights into differences between participants and non-participants in public consultation programs, the results presented below are compared between individuals who participated in the rezoning public consultation process (participants) and those who did not participate (non-participants).

Profiling Fishers

The majority of respondents to the mail survey were males (84%, n = 788) between the ages of 31 and 60 (64%), with an average of 29 years total fishing experience and 23 years experience fishing in the GBRMP. Most fishers (75%, n = 769) reported that fishing is their first or second most important recreation activity in the GBRMP. Overall, the most fishers believed that the zoning was a good idea (70%, n = 788), were supportive of the plan (58%, n = 775) and some fishers reported familiar with the zoning plan (44%, n = 490).

Level of Engagement, Motivations and Perceptions of the Rezoning Consultation Process

Fishers' level of participation in fisheries management issues was measured by asking whether they had ever attended a public meeting or made a submission to the GBRMPA concerning the 2004 rezoning. Of the 766 fishers who answered the question about public involvement in public consultation programs, 320 (42%) were classified as 'participants' as they reported attending a public meeting or making a submission concerning the 2004 rezoning, while 58% were classified as 'non-participants'.

Results indicate that the level of trust in the management agency was among the most important factor influencing fishers' level of engagement and motivation to participate in fisheries and marine park-related issues. Fishers were asked to rate their level of agreement with a series of statements about trust in the management agency and the consultation process of the GBRMP. Significant differences ($p < 0.001$) between participants and non-participants were found in 5 of 7 statements about the management of the GBRMP related to trust in the management agency and in the consultation process (see Appendix C for a detailed list of statements and level of agreement categories).

Compared to non-participants, participants were more likely to disagree that the GBRMPA is doing what is best for the conservation of the GBR (49%), that the GBRMPA considers the concerns of recreational fishers when making decisions about management of the Marine Park (60%), and that the GBRMPA is doing a good job of managing the GBR (44%). Participants also disagree that recreational fishers received fair treatment in the 2004 rezoning process, and they do not believe that recreational fishers were adequately consulted (57%). No difference was found regarding statements about the enforcement of the zoning and on the availability of the information on the zoning process. In both groups, most fishers believe that the “Zoning of the Great Barrier Reef is adequately enforced” (P = 46%, NP = 39%) and that “Information about zoning in the Great Barrier Reef is readily available to recreational fishing” (P = 80%, NP = 77%).

Fishers were asked whether they believe government agencies responsible for fisheries and marine park management should consult the public (including recreational fisheries) about fisheries and marine park decisions. The large majority (97%, n = 754) believe the public should be consulted, while just 3% reported the public should not be consulted by government agencies. Fishers who answered affirmatively (n = 731) to the question about whether the public should be consulted about fisheries and the Marine Park issues were asked to rate the importance of 18 possible outcomes and attributes of public consultation programs (Table 5.2).

Table 5.2. Level of importance with statements about attributes/outcomes of public consultation programs rated as highly and lowest important by participants (P) and non-participants (NP).

Elements of consultation programs (summary)	Level of Importance (% of respondents) P	NP
Follow a process that is easily understood by everyone	88	87
Result in the best outcome for the marine environment	84	84
Do not allow any one group to have too much influence in decisions	83	81
Allow local concerns to be incorporated into decisions	83	68
Give people a genuine opportunity to influence decisions	82	70
Allow citizens to express their opinions to resource managers	81	70
Favour the group with the most at stake	34	31
Do not cost the government too much money	27	19
Do not require too much time for people to participate	11	11

Colour Scale						
Percentage	0	0-20	20-40	40-60	60-80	80-100

* See Appendix C for a detailed list of statements and level of importance categories.

Although the level of importance for elements of an effective public consultation programs was generally moderate or high among both groups, participants and non-participants differed significantly ($p \leq 0.01$) in their level of importance with 9 of 18 belief statements (see Appendix C). Compared to participants, non-participants were less likely to find important that public consultation programs 'Give equal opportunity for all citizens to participate', 'Result in the best outcome for recreational fishers', 'Result in an outcome that is fair to all affected groups', 'Give people a genuine opportunity to influence decisions', 'Improve the relationship between resource managers and citizens', 'Allow local concerns to be incorporated into decisions', 'Involve the public at all stages of planning', and 'Give special consideration to the concerns of recreational fishers'.

Fishers in the face-to-face interviews were asked an open ended question on why fishers should be consulted (or not consulted) about fisheries decisions. Qualitative coding of open-ended questions from the face-to-face interviews (see Appendix C for a list of codes and comments) revealed that both participants and non-participants believe that the main reasons for resource management agencies consulting the public are: (i) the right to be informed (consulted), (ii) improves consultation, (iii) incorporates local knowledge, (iv) enhances transparency, and (v) economic attachment. Overall, recreational fishers believe that as stakeholders they have the right to know what is happening. As "shareholders" in the reef, fishers believe they have ownership in all issues affecting the reef and its resources and that therefore, they should be consulted in resources management-related issues. They also assume that their participation will improve the consultation process because they can provide genuine local knowledge and at the same time educate themselves. Participants also believe that participation of recreational fishers would assure transparency to the consultation process. Finally fishers stated that because recreational fishing is an expensive activity that provides financial benefits for the local economy, their opinion should be considered. Conversely, those who believe that resource management agencies should not consult the public believe that management agencies know how to best protect the environment and that public is too emotive and unqualified to make decisions (see Appendix C). Non-participants also believe that resource management agencies have the expertise to make proper decisions. These results support the results from the closed ended questions in the mail survey.

Fishers who responded negative to the question about whether management agencies should not consult the public (n = 22) were asked to rate their level of agreement/disagreement with a series of 6 statements about why the public should not be consulted about fisheries-related issues (see Appendix C for a detailed list of statements and level of agreement categories). Statements receiving the highest level of agreement were “Consulting the public allows some interest groups to have too much influence in decisions” (85%), “Fisheries and marine park managers know what is best for our natural resources” (67%), and “Consulting the public delays the implementation of important management changes” (66%).

Qualitative coding results of open-ended interview questions from the face-to-face interviews indicated that lack of trust in the management agency and in the consultation process was a major reason for some fishers believing that the public should not be consulted (see Appendix C for a list of codes and comments). Those people perceive the engagement process as not useful because they think their opinions were not taken into account in the decisions made. Another reason given for government agencies to not consult the public is that management agencies have technical expertise for make informed decisions, while the public opinion is unqualified and emotionally attached to the subject under decision.

Furthermore, most fishers believe that the zoning plan needs to: (i) be reassessed (mainly in regard to the location of green and yellow zones close to coastline and beaches), (ii) include rotation zones (for instance, open green zones for a year then them close them again, or alternate blue to yellow and yellow to green every five years), and (iii) better incorporation of scientific data (better linkages between research-based data and the need for the zones) (see Appendix C for a list of codes and comments). Overall, recreational fishers reported dissatisfaction with the methods used to consult the public over the recent re-zoning of the GBRMP. To better understand this issue, fishers were also asked about their perceptions on a range of techniques commonly used to provide information to fishers and gather their input into management decisions affecting recreational fishing.

Consultation techniques

Respondents were presented with a list of 11 techniques that could be used to educate and engage people about fisheries and marine park management issues, and asked to rate each one as either not at all useful, moderately useful, or very useful. Most fishers believed that all of the techniques were moderately or very useful (see Appendix C for a detailed list of techniques and level of perceived usefulness categories).

The techniques rated very useful by the highest number of fishers were “Public information displays” (P = 83%, NP = 84%), “Educational brochures and pamphlets” (P = 75%, NP = 76%), and “Engagement of recreational fishers in research” (P = 65%, NP = 62%). Although the level of usefulness for public consultation tools was generally moderate or high among both participants and non-participants, there were significant differences between the groups in 3 of 11 items presented (see Appendix C). Compared to non-participants, participants were more likely to attribute a high level of use to (a) ‘public meetings’, (b) ‘requests for formal written submissions’, and (c) ‘public hearings’.

Use of mapping and spatial tools

Mapping and GIS were the main tools used to consult stakeholders and to analyse spatial-related information on the rezoning process of the GBR. In this section, the usefulness of such tools was analyzed in an attempt to understand how recreational fishers perceive and use mapping and geographic information tools in fisheries-related issues and as an effective way to engage people in management processes. Fishers were asked to rate their level of use with maps and mapping tools in the course of their activities (Fig. 5.11).

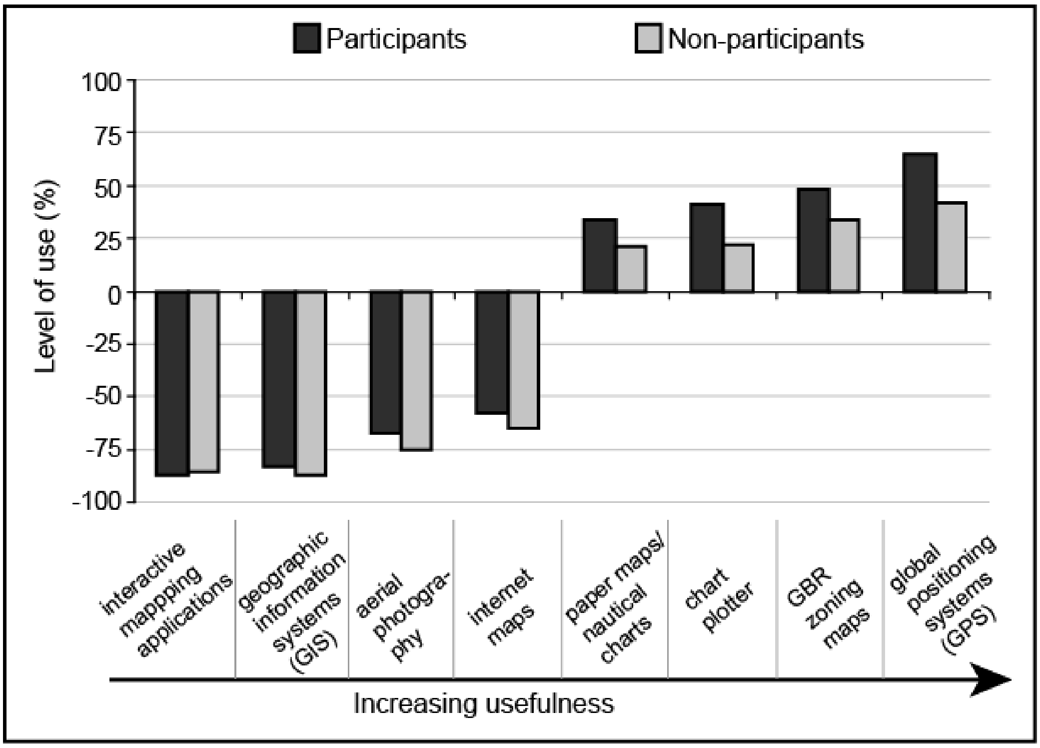

Figure 5.11. Level of use of maps and spatially related tools.

Although the level of usefulness was similar between groups, participants and non-participants differed significantly on their level of use with 4 of 8 maps and mapping tools (see Appendix C for further details). Compared to non-participants, participants were likely to report a high level of use with the following tools (i) GPS, GBR zoning maps, (iii) chart plotter, and (iv) paper maps/or nautical charts. Overall, conventional mapping tools (e.g. paper maps, plotter) were reported as most useful by recreational fishers than more innovative techniques such as GIS and interactive internet-based maps. Qualitative coding results of open-ended interview questions indicate that the main advantages of conventional tools include accuracy (e.g. GPS and chart plotter provide good accuracy for mark fishing spots and bottom structures), avoiding green zones (e.g. GBR zoning maps help identify the green areas), and navigation (e.g. GPS, chart plotter, and GBR zoning maps). Conversely, reasons for not using innovative spatial tools were lack of knowledge or access, inappropriateness of the information provided (e.g. aerial photos and internet maps show bottom structures), and inadequate scale (e.g. internet maps). Outside of the scope of fishing activity, most fishers do not commonly use mapping and other spatial-related tools. Among the few uses outside fishing, fishers also use maps and mapping tools to plan fishing trips (mainly through internet maps and aerial photos), and to look at hydrodynamic information.

5.4 Discussion

The current investigation has revealed the extent to which management changes in the rezoning of the marine protected areas in the GBR have affected recreational fishing access to the marine resources in selected areas of the GBRMP. Through assessing observed spatial and related-social implications of the 2004 management changes of the Marine Park on recreational fishing activity and recreational fishers, some interesting and useful findings have been discovered. These findings are discussed in the following sections.

Implications of management changes for recreational fishers' participation in and adaptation to marine spatial planning

This study has demonstrated that the integration of on-ground research with spatial assessment is a useful approach for eliciting fishers' perceptions and highlighting the impacts of the marine zoning on the recreational fishing community. It has also demonstrated the usefulness of PPGIS related spatial tools in documenting and reflecting the implications of the observed spatial changes in the distribution of recreational fishing effort in response to the 2004 rezoning of the GBRMP. Current and potential management changes are likely to influence recreational fishers' participation in planning and their access to fishing areas in the GBR. This research is particularly relevant to the impending review of the 2004 rezoning plan expected in 2011. The results provide valuable information that can support understand the implications of, and recreational fishers' social and spatially-related responses to, management changes.

Results suggest that failure to adequately consider recreational fishers' spatial substitution decisions resulted in a number of negative impacts on recreational fishers (e.g., displaced fishing effort towards inshore areas, increased crowding in popular fishing areas) and on the Marine Park (e.g. increased fishing pressure in areas remaining open to recreational fishing and to previously less exploited areas). Identification of the drivers of the spatial distribution of fishing effort, factors affecting fishers' choices of locations and adaptation strategies adopted by fishers provide a valuable tool to help understand the impact of spatial fishing closures on fishers and resources. Findings also provide a basis for improving the engagement of fishers' and their values in management issues that affect fishers' access to areas of the GBRMP.

Mapping-based information and spatial analysis techniques supported the collection, analysis, and communication of management changes regarding the 2004 GBR rezoning, which at the time was the most extensive planning and consultation process for marine management in

Australia and worldwide (Fernandes *et al.* 2005). This study found that recreational fishers also agree that spatial-based information and tools are a useful way to inform, consult and engage fishers in fisheries and marine park management. However, fishers reported a high level of dissatisfaction and distrust with the way the spatial information was collected in the consultation process was used in the rezoning plan. They believed that the information was used to support the management agency in the selection of the green zones instead of avoiding overlap with fishing areas. Some fishers had more than 50% of their locations turned into green zones. The perception that the spatial information provided during the consultation process was used against fishers' interests might affect the reliability of mapping-based information affecting its utility and increase the bias in future consultation processes. The GBRMPA now faces the challenge of overcoming the sense of distrust and developing other ways of collecting spatial-related information for the upcoming review of the rezoning plan.

The early engagement of fishers in problem identification, design, and collection of spatially-related information provides resource users with a practical context and a better understanding of spatial information and GIS tools in public engagement and participation processes. Early engagement of fishers in a practical context was an important strategy adopted by this research. Recreational fishers were involved early in the project supporting the design of questions, collection of data, and validation of pre-processed and final results. Previous and long-term connections established between researchers at the Fishing and Fisheries Research Centre at James Cook University, and recreational fisher groups, such as CapReef, were a key factor in conducting the present study. Development of collaborative projects and the participation of researchers of the Centre as members of fisheries steering committees are an example of such integration. Although more time-consuming and costly, this approach promoted ownership of the project which was also enhanced by established relationship and trust built between researchers and key members of the recreational fisher community. In addition, data collection and analysis was conducted by knowledgeable research-based people in an interactive way. Continuous feedback and updates on the progress and outcomes were critical for building fishers' support and participation in the project.

Therefore, if the impending review of the rezoning plan intends to truly facilitate and encourage a meaningful public engagement process while overcoming barriers to communication (Thompson *et al*., 2004) faced by the 2004 rezoning process, a different approach is necessary. Despite the efforts on the part of GBRMPA, there were still significant impacts on recreational fishers and significant distrust in the recreational fishing community. The involvement of stakeholder groups such as recreational fishers only in the implementation phase of the 2004 rezoning of the GBRMP has resulted in dissatisfaction with the engagement process (Sutton &

Tobin, 2009). Recreational fishers' in the GBR are mostly dissatisfied with the consultation process due to perceptions of pre-determined outcomes, inadequate consideration of stakeholders' interests, and insufficient feedback about how the information provided by recreational fishers was used in the rezoning process. Results of this study corroborates with the findings of Sutton & Tobin (2009) and Teh-White *et al.* (2004) and suggest that an early and continuous public engagement with a more focused and structured approach is critically necessary.

Furthermore, stakeholder groups along the GBR need to be more prepared, and learn from previous experiences. It has been three decades since the 1980s when discussions raised the need for higher levels of biodiversity protection and the first zoning plans were developed covering main sections of the GBRMP. Management changes will continue to happen in response to political pressure, public demand or naturally-driven process. Two-way and active participation requires that resource users clearly express their views and claim their stake in the different phases (from need to implementation and evaluation) of the management plan.

Displacement of recreational fishing effort and fishers' adaptation strategies

Information on changes and adaptation strategies in response to management decisions are of great importance for both resource users and managers (Powers & Abeare, 2009). Susbstitutability (Gentner & Sutton, 2008, Sutton & Ditton, 2005) and site choice (Hunt, 2005, Valcic, 2009) in recreational fishing are important topics for management to understand how fishers make substitution decisions when constrained by the establishing of no-fishing areas (Shelby & Vaske, 1991). The combination of behavioural changes in response to factors that constrain participation such as implementation of regulations, reduced access and increased cost, is characterised as displacement (Sutton & Ditton, 2005). Although critically important to the achievement of management objectives of MPAs, not much investigation exists on the spatial adaptations by fishers to the implementation of fishing closure regulations (Murawski *et al.*, 2005, Valcic, 2009).

A better understanding of the effects of spatial closures on recreational fisheries displacement in access to fishing grounds and species will not only support fishers to determine the likelihood of a satisfactory experience, but it might also strengthen fishers' awareness about the importance of conservation initiatives to the GBR. Information on spatial- and social-related adaptation strategies to zoning processes will support managers to better predict shifts in fishing effort.

Management agencies will benefit from enhanced information on recreational fishers' responses in the face of management closure regimes (Daw 2008; Valcic 2009). Improved understanding of the effects of spatial closures on fisheries displacement in access to fishing grounds and species also provides resource users useful information on how fishing choices will be affected by the implementation of no-take areas (Sanchirico *et al.*, 2002) and the impacts of associated distribution of human pressures on marine resources (Stelzenmüller *et al.*, 2008).

In the northern and southern parts of the GBR, most recreational fishers lost at least one of their regular fishing locations under the new Zoning Plan, and travel distances to fishing grounds have substantially increased. To compensate for the loss in fishing grounds, affected individuals have either increased their fishing effort at other locations that remain open or shifted their fishing activity to substitute (and in many cases less exploited) areas within the Marine Park. Some fishers have also compensated for the loss of areas by increasing their fishing frequency. The combined results of fishing compensation strategies and regular fishing locations that are still open to fishing reflect where and how much fishing effort has been displaced. Results reflect a significant displacement of fishing effort towards inshore areas in both study sites. In most cases, high intensity use fishing locations are located close to the coast and are also concentrated nearby or around borders of submerged structures, particularly reefs, shoals and banks.

The application of an integrated social-psychological and economic approach by Gentner and Sutton (2008) for understanding displacement and substitution options in recreational fishing shows that major substitutability strategies used by displaced fishers include replacement of locations, substitution of targeted species or alteration to different activities. Gentner and Sutton (2008) found that in the face of trade-offs, constraints, or changes in the quality of fishing experience, fishers tend to select alternative fishing locations that most closely resemble their original experience and maximise the benefits (utilities) they obtain from participation in fishing. Substitution might also involve changes in the timing or frequency of participation in fishing activities. For example, when constrained by reduced access or increased costs, fishers may respond by targeting alternative species or fishing at substitute locations that provide them with similar benefits (e.g. challenge and setting characteristics of targeting preferred species) and provide them the greatest utility (Gentner & Sutton 2008; Hunt 2005). This might explain, for instance, the reason why interviewed fishers of the GBR tend to select new locations close to the favorite spots that are no longer available for fishing.

Gentner and Sutton (2008) also suggest the importance of considering the relationship between commitment to fishing and substitution in explaining fishers' substitution decisions. They found that committed fishers who invested more time, energy and money into fishing activity are more likely to reject other activities in favour of fishing. Less committed fishers, compared to committed fishers, are more attached to fishing and less likely to replace fishing by other activities that would not provide them with the with similar benefits and satisfaction. Attachment to targeted species and associated perceptions of travel distance, costs and conditions of fishing quality are commonly linked to substitutability in recreational fishing.

Findings of this study are consistent with previous research which suggested that spatial patterns and trends in fishing effort allocation are influenced by the combination of technical considerations (e.g. targeted resources, habitat types, costs) and social factors (e.g. individual fishers' behaviour, encounters with other fishers, fishing regulations) (Daw, 2008, Hunt, 2005; Kangas, 1995, Lynch, 2006, Powers & Abeare 2009; Stelzenmüller, *et al.*, 2008, Walters & Martell, 2004). Reasons influencing fishers' choices on fishing grounds among GBR recreational fishers were divided into two groups, locations closer to the coast, and those away from the coast. Locations closer to the coast were preferably because of accessibility (travel distance and travel time), proximity to home and boat ramps, provision of shelter and safety, targeting of specific species, productive areas/good fishing, and other leisure related activities such as being with friends, boating and relaxing, and fishing competitions. High intensity use fishing grounds located more distant from the departure points were mainly chosen due the quality of fishing (productive areas), reduced number of people, alternative fishing spots, and other environmental related aspects (e.g. scenic view, scuba dive).

Even though 66% of the GBRMP is still open for recreational fishing, the results of this study show that not all of the available places are perceived as a satisfactory alternative or substitute for replacing the favorite sites that are no longer available for fishing. Overall, site substitution and species substitution are the main spatial substitution alternatives reported by recreational fishers of Townsville and Rockhampton (Fig. 5.12). For instance, if a fisher is highly connected with fishing specific species at a particular place, then he might replace the lost areas by fishing more at other favorite areas that are still open for fishing, (upper left quadrant of Figure 5.12). In this case, no spatial or species displacement occurs, but an increase of fishing effort takes place at those locations. If their locations that are closed somehow differ from their locations that are left open (in terms of habitat or species availability), then this can result in a shift in target species (upper right quadrant of Figure 5.12) if their preferred substitution strategy is to fish more at their other favorite locations.

Location	Target species: same	Target species: different
prior still available	**no substitution** fishing more at previous exploited spots	**resource substitution** increase fishing effort to alternative coastal species
new	**site substitution** similar location - target specific species	**total substitution** replace species and fishing sites

Figure 5.12. Substitution and compensation scenarios for recreational fishing at the GBR (Source: Adapted from Gentner & Sutton, 2008. The typology of substitution alternatives for recreational fishing was originally proposed by Shelby & Vaske, 1991).

However, if a fisher moves to a new location but keeps fishing the same species (lower left quadrant of Figure 5.12), then the fishing effort will be displaced to previous less exploited areas and a site substitution occurs. In this scenario, fishers tend to select a location that most closely resembles their original experience and maximise the benefits (utilities) they obtain from participating in fishing. Finally, a total substitution (right lower of Figure 5.12 occurs when an individual decides to change both location and target species.

Results presented in section 5.3.1.4 show that 29% of fishers reported change of targeted species as the result of the displacement imposed by the 2004 rezoning of the GBR. Most of the displacement tended to be in inshore and non-reef areas and as a consequence, the substitution for different species presented in two of the substitution scenarios (upper right and lower right quadrants of Figure 5.12) are likely to affect most estuarine and coastal species. In addition, potential conflicts can emerge from the aggregation of fishers on the remaining grounds. The concentration of recreational fishing may result in crowded fishable waters and competition for space and resources might emerge (Sanchirico *et al.* 2002).

The fishing substitution alternatives are not restricted to the options presented in Figure 5.12. Activity substitution, for instance, might occur in situations of no-take areas where exploitation of any resource is not permitted and a fisher chooses to switch from fishing in favor of other activities (e.g. hunting, swimming) rather than substitute locations or species. Replacement of fishing activity was not reported as an alternative among the recreational fishers of the studied sites. Extensive activity substitution is not likely because of the large areas of the GBRMP that remain open to fishing. However, activity substitution (and therefore displacement from the fishery) cannot be discounted because of the sampling strategy. That is because in this research focused on current fishers so those who were displaced would not have been included in the sample.

In any scenario, different costs are associated with different substitution and adaption strategies. Fishers' will select fishing sites that maximise their fishing benefits and personal expectations, at the lowest cost possible. For instance, the congestion of fishers on remaining grounds because of the reduction on the amount of area open to fishing might increase fuel usage (e.g. by traveling further distances) and higher capital costs (e.g. by acquiring new gear if shifting from shallow to deep water line fishery) (Sanchirico *et al.* 2002). Therefore, it has been suggested that changes to the cost of fishing may also influence changes to fishing behaviour (Mapstone *et al.*, 2008). The increase in fuel costs in the few years after the rezoning has undoubtedly had an impact on fishers' substitution behavior within the GBRMP. It might involve, for instance, changes in fishers' perception of what constitutes a satisfactory fishing experience as well as changes in the timing or frequency of participation in fishing activities.

Socioeconomic factors such as accessibility (mainly related to fuel and equipment costs, and increased travel time) and proximity to home and boat ramps highly influenced fishers' choices for recreational fishing spots. Familiarity with the area also affected fishers when selecting new fishing spots which, in most of the cases, tended to be located close to a previous fishing location. Additionally, the existence of land-based facilities such as boat ramps, road access, camping and barbeque infrastructure were also important attributes in selecting fishing sites. Therefore, other factors besides fishing quality also contribute to fishers' selection of fishing sites. This information provides managers additional opportunity to influence fishers' displacement by using other approaches besides fishing regulations (Hunt, 2005). The improvement of facilities near available fishing sites might enhance the utility of these places to fishers and influence the allocation of fishing effort in surrounding areas.

Perceptions of rezoning and participation in fisheries consultation process

Fishers' participation is an essential factor contributing to effective implementation of fisheries and marine protected areas management strategies (Baelde, 2005, Granek et al., 2008, Lloret et al., 2008, Silver & Campbell, 2005, Sumaila et al., 2000). This assessment of the effects of observed spatial changes for fishers' satisfaction, attitudes and level of engagement in fisheries and marine park management demonstrated that dissatisfaction with the rezoning and consultation *processes*, rather than dissatisfaction with the *outcomes*, constitute aspects of major opposition towards the Zoning Plan. Most of the fishers believe that the 2004 rezoning was a good idea to protect biodiversity and enhance sustainability of marine resources, particularly fisheries, in the GBR. However, a significant number of recreational fishers did not believe that the concerns of recreational fishers were adequately considered in the rezoning process, resulting in a low level of trust in the GBRMPA among recreational fishers (see Appendix C for a list of codes and comments). This result corroborates with other studies about participation and participatory research in the context of natural resource management. Barreteau *et al.* (2010), for instance, report that participants are likely to be disappointed in situations where they experience unexpected feelings, a lack of pleasure, a lack of control over the process, and/ or some breach of their legitimacy. According to Barreteau *et al.* (2010), such disappointment might be related to two main differences related to process and results (1) the difference between the actual process as it has been perceived and the process as it had been expected, and (2) the difference between the actual results and the results that were expected to be produced by the process. In any case, disappointed participants are more likely to decline participation in new opportunities for involvement in future processes.

One of the most common explanations for this gap between people's positive attitudes but opposition towards some situations has been characterised as the NIMBY ('Not-In-My-Backyard') effect (e.g. Grafton & Kompas 2005; Jankowski & Stasik, 1997; Suman *et al.*, 1999; Swofford & Slattery, 2010). The implicit assumption of the NIMBYism concept is that usually local participants are seeking their own individual interests, rather than the societal maximum utility for the common good. In other words, those individuals closer to an unwanted facility (or situation) are more likely to be opposed to it being sited within their locality (Swofford & Slattery, 2010). They tend to have positive attitudes until they are actually confronted with it, and then they oppose it for selfish reasons. The term 'backyard' is frequently used in NIMBY discussions to imply some geographic area for selfish behaviour (van der Horst, 2007).

Research on the policy implications of the establishment of marine reserves in Florida and New Zealand indicates that fishers may favour, in general, the establishment of reserves, but not in specific areas where they might fish (Grafton & Kompas, 2005). In the Florida Keys National Marine Sanctuary, Suman *et al.* (1999) found that a large number of stakeholders recognized the benefits of harvest refugia of the proposed zoning plan but preferred not to have one in their vicinity. In this case, local fishers' residents and commercial fishers generally tended to support the marine conservation efforts but this support substantially reduced when the boundaries drawn on a map appeared too close to their fishing grounds.

Nevertheless, some authors argue that the NIMBY concept is flawed and inadequate way and that the term *"has rightly been criticised on the grounds that it fails to reflect the complexity of human motives and their interaction with social and political institutions"* (Bell *et al.*, 2005: 460). In a recent study, Swofford & Slattery (2010) showed that the use of the Nimby phenomenon did not adequately explain the opposition attitudes of local residents towards the development of a wind energy farm in the state of Texas, United States. Their findings indicate that, although those living closest to the wind farm were least favourable towards the project, there was still an overall positive attitude towards the wind farm. In fact, nearly half of all respondents (46.6%) were willing to support wind farms on their property and a very small portion (13.8%) did not support wind farms. They concluded that those individuals opposed to the wind farm were too small of a minority to indicate NIMBY-like behavior. Alternatively, Swofford & Slattery (2010) suggest that other factors such as inadequate communication, late public engagement, existence of a top-down planning model, and lack of transparency in the decision making process better explained communities behavior towards the implementation of wind farms in Texas.

In the Great Barrier Reef context, recent results presented by Sutton & Tobin (2009) revealed that recreational fishers in the GBR evaluate conservation and management initiatives in broader terms, considering not only the impacts of management actions on their fishing activity, but also the long-term conservation and environmental outcomes of decisions and the adequacy of the process used to develop and implement specific policies. Their study shows that, although most direct effects will be experienced by those who might depend on and use this environment and its resources more often, a complexity of issues other than just the NIMBY influence recreational fishers' attitudes towards the 2004 rezoning of the Great Barrier Reef Marine Park. Fishers' general and specific attitudes towards the zoning plan were significantly influenced by their beliefs about the conservation benefits of the plan, the necessity of the zoning plan, the adequacy of the consultation program, and the impacts of the zoning plan on their recreational fishing activity. More specifically, findings by Sutton & Tobin (2009) using a logistic regression model indicates that fishers were more likely to believe that rezoning of the Marine Park was a 'good idea' and more likely to 'support' the plan if they believed that rezoning the Marine Park was necessary, the zoning plan had high conservation benefits or the consultation program was adequate. In addition, results revealed that many recreational fishers are willing to forego access to some areas in support of efforts to increase long-term protection of the Reef because these conservation efforts are consistent with the multiple values they hold towards the marine environment. Finally, Sutton & Tobin (2009) suggest that that it is possible to generate support from individuals who do not support a policy in principal and minimise the NIMBY related effects by better promoting the necessity of a policy change, minimizing its impacts on affected stakeholders and supporting engagement that meets stakeholder needs and aspirations. They argue that considering such issues can be instrumental in maintaining the support of those who agree with a policy, and in gaining the support of those who do not despite being in their backyard.

In this research, the perception of the rezoning as a top-down agency driven process, and fishers' beliefs about the low impact of recreational fishing (compared to other extractive activities; e.g. commercial fishing), greatly influenced fishers' engagement in the rezoning process. For instance, information from open-ended interview questions revealed that most fishers consider recreational fishing as a totally sustainable activity and other existent mechanisms (e.g. size and bag limits) are sufficient to protect marine resources. Therefore, recreational fishers do not agree that the same percentage of exclusion should be applied equally to all users. They also questioned the inflexibility of the 25% increase in non-take areas established by the rezoning and they think this value should also have been part of the public consultation process. Likewise, they believe that individual opinions provided throughout mail-based zoning maps submissions were not taken into account and that lack of time prevented them from being better organised and to submit collective opinions.

Fishers also perceived the establishment of green zones as a pre-determined decision, despite the fact that the GBRMPA states that many changes were made in the rezoning plan in response to the information collected through the public consultation process. The perception of a symbolic participation in public meetings is also described as a major constraint in fisheries management in United States and Kenya (Glaesel & Simonitsch, 2001). In the American case, participation of fishers in the management process is characterised as a pseudo-participation including consultation and information but preventing true partnership through delegation of power and cooperation.

These results corroborate the findings of Sawynok (2007) in documenting recreational fishing views about their involvement in the MPA process. Sawynok (2007) found that fishers perceived that they were marginalised and had no influence in the final result of the rezoning. He also found that fishers believe that consultation was a waste of time because decisions had already been politically established previously to the consultation process. The results are also in line with Day (2008) who reported that misconceptions about the zoning scheme were a major obstacle towards an effective implementation of the GBR Zoning Plan. Among the main misconceptions presented by Day are (i) the belief that the Marine Park was zoned when implemented, (ii) lack of understanding of the role played by the zoning as one of many management tools in the Marine Park, and (iii) perception of the zoning as confined just to waters not considering its integration with airspace and seabed.

Improving communication and providing useful ways to involve the recreational fishing community can not only minimize or mitigate preconceived misconceptions, but also increase representativeness of recreational fisheries in the management of fisheries and the GBRMP. The results indicate that 58% of the recreational fishers in the GBR region did not attended a public meeting or make a submission to the GBRMPA concerning the 2004 rezoning processes. This findings corroborate a previous study of Sutton (2006b) who suggested that fishers participating in public consultation programs may not be representative of the wider recreational fisher population in Queensland. Fishers who had attended a public meeting or made a submission regarding to the plan were more likely to not trust in the management agency and to disagree that their concerns were adequately incorporated into the plan (Sutton, 2008). Therefore, there is a substantial tendency for consultation programs to result in biased and misleading understanding of recreational fishers' expectations and to produce unrepresentative outcomes (Sutton, 2006b).

Results from recreational fishers suggested that the vast majority of fishers believe that management agencies should consult the public about fisheries and marine park management issues. For those, a meaningful engagement process should follow a process that is easily understood by everyone and participants should be given the opportunity to express their opinions to resource managers. It should also ensure that local concerns are incorporated into decisions, and not allow any one group to have much influence over the process. Overall, it would be a process that gives people a genuine opportunity to influence decisions that result in the best outcome for the marine environment. However, in practice, fishers felt not realistically engaged in the rezoning management process. As stated previously, the perception of the rezoning as a top-down agency-driven process resulted in distrust in the management agency and in a low impact of recreational fishing in influencing the final outcome. Without cooperation and participation of fishers, the ability of fisheries managers to make well-informed policy decisions is limited (Silver & Campbell, 2005). This might lead to tension between fishers and government, low compliance with regulations, and policies that do not reflect the fishery context (Silver & Campbell, 2005).

In regard to the engagement tools used to consult the public during the rezoning process, a large majority of recreational fishers believe that tools used at information and collaboration stages of participation (public meetings, written submission, and public hearing) are important. However, fishers are not satisfied with such tools. They claimed that information was not provided in a timely manner and that the consultation process was not representative at the local scale. The techniques rated as very useful by the highest number of fishers were public information displays, educational brochures and pamphlets and engagement of recreational fishers in research. Such techniques are represented by information (public information displays, educational brochures and pamphlets) and involvement (engagement of recreational fishers in research) levels of the public participation spectrum. Therefore, based on the preferred techniques for public consultation, recreational fishers' participation in fisheries and marine park management issues can be categorised as low (information) and medium (involvement) levels of the public participation typology (e.g. Arnstein, 1969, Jonsson, 2005, Weidemann & Femers, 1993).

Results also indicate that recreational fishers of the GBR desire more timely information and engagement in recreational fishers in research which characterises information and involvement levels of public participation. However, when considering the public participation and community involvement process, they identified a higher level of participation, between involvement and collaboration. Recreational fishers desire an engagement process that not only allow them to express their views, but that also incorporates their concerns and give them the ability to influence the outcomes of the decision-making process. Engagement through involvement and collaboration in the MPA process can have a significant impact for meaningful participation of recreational fishing on conservation efforts (Granek *et al.* 2008; Lloret *et al.* 2008; Sawynok 2007).

This study suggests that the upcoming review of the 2004 rezoning announced for 2011 needs to adopt a more structured, adaptive and participatory approach. An early and continuous stakeholder participation and involvement process needs to be promoted and sustained through the entire planning and management processes. Engaging recreational fishers and their knowledge in research and management constitute a meaningful approach to involve the recreational fishing community in planning and management of fisheries and marine park issues.

5.5 Limitations of the Research Findings

This study has addressed significant spatial and linked social factors of the implications of rezoning management changes for fisheries and marine park managers in two case study situations in Queensland. In doing so, some limitations were found which may influence interpretation of the results.

Firstly, data provided by the face-to-face interviews and the mail survey might not be representative of all recreational fishers of the northern Queensland coast for the following major reasons:

(i) The face-to-face interviews did not target a random or representative sample; rather they sampled knowledgeable and avid fishers who could provide data on fishing locations. Clearly this may limit the ability to generalize. The spatial data, in particular, should be interpreted as indicative of the distribution of recreational fishing and fishers' substitution patterns within the context of the study sites investigated by this research. The recreational fishers interviewed supported and agreed on the use and report of the provided data in an aggregate form as a way to better understand how fishing choices were affected by the implementation of no-take areas. The spatial-related results should not be extrapolated as representative of the entire GBRMP and the recreational fishing population.

(ii) In the mail surveys, a more random sample approach was used, but due to non-response bias, more avid and experience fishers were slightly over-represented in the mail survey (Sutton, 2008). Therefore, this potential bias should be taken into consideration when viewing and using the results of this study. For instance, highly committed fishers and those characterised as non-participants in the public consultation program represented the majority of the sampled population.

Secondly, fishers' preferences for offshore species also need to be interpreted with caution. This preference for saltwater species does not necessarily reflect the species preferences of the general recreational fisher population. However, this result was expected because the study targeted people who fish in the GBRMP, which means a bias towards offshore fishers.

Thirdly, data used in this chapter were collected in conjunction with a state-wide recreational fishing survey conducted from March 2006 to December 2007 to investigate the effects of the 2004 rezoning of the GBRMP on the recreational fishing community. Over the last 2 years, recreational fishers' aptitudes and perceptions of the Zoning Plan and its implications on recreational fishing may have changed or adapted. Unfortunately, no data has been collected since 2007 that allow us to assess potential changes in attitudes, behaviour and perceptions of fishers. Continued investigation of spatial and social aspects of fishing will also be essential for ensuring that significant changes are captured both spatially and temporally.

Fourthly, the development of a more robust index of fishing pressure was limited by the lack of data on catch per unit effort, insufficient information of fishing departure points (assumed in this research as being the closest boat ramp on the coast) and inaccurate data on the number of recreational fishing trips per year. Nevertheless, the current index based on the accumulated number of fishing locations per recreational fisher weighted by the category of fishing frequency provides initial indicator of recreational fishing concentration and displacement.

Finally, this study examined the spatial effects of the rezoning on recreational fishing activity and recreational fishers map-based interviews as the data collection method. Uncertainties related to collection and interpretation of mapping-based information may have influenced the results. Anecdotal research on cognitive spatial knowledge suggests that people's construction and translation of geographic-related information is influenced by how they perceive and interact with their context (Close & Hall 2006; McCall, 2003; Prigent *et al.* 2008). Errors associated with misjudgment or misinformation from interviewees in collecting spatial-related data may also affect the accuracy of the map-based information (Daw 2008). Additionally, map bias associated with map scale, generalisation of features and translation of paper map information into GIS database can all contribute to potential data errors (Close and Hall 2006). For example, large map scales (e.g. 1: 20 000 or less) may obscure important reference features for fishers such as shoals, reef edges and island points. The collection of map-based data may also be influenced by who is interpreting the spatial information (e.g. the interviewee or the interviewer) (Close and Hall 2006). Close and Hall (2006) state that while the locations marked by the harvester's finger are both discrete and representation of reality, line information drawn by an interviewer represents a generalisation of the reality. Such data is usually represented by point or lines and therefore single and multiple buffer solutions are needed around the original feature. However, polygon features already are generalisations and less likely to be affected for sources of errors as the points or lines of representation.

In the present research, some of those errors described by Close and Hall (2006) and Prigent *et al*. (2008) were minimised, but not excluded. Map scale and accuracy errors were reduced by collecting data using the same zoning maps with which fishers were already familiar. Problems with generalization of spatial information on previous and current fishing locations were minimised by letting the fishers draw their fishing locations on the zoning printed maps. Errors in data translation from paper maps to GIS database were reduced by using an on-screen digitising process in which a faithful representation of the paper map information was digitised and the same zoom approximation applied for all maps. However, it was not possible to control the influence of the context and previous experiences of fishers over the mapping data collected.

5.6 Chapter Summary

The coupled ability to visualise and analyse spatial data provided by mapping and GIS tools with the contextual information acquired by surveys and interviews constitute a comprehensive approach to understand social and spatial aspects of the rezoning of the GBRMP. Findings help understanding how spatial data and geographical information tools are currently used in managing the GBRMP, and how such tools can be better designed to address and represent stakeholders' interests in GBRMP management decisions. Such information provides a framework to better understand recreational fishers' spatial knowledge and fishing behaviour over the GBR coast.

The intersection between public interests about implications of management changes and the use of GIS technology represents a valuable way of documenting and understanding the effects of no-take zones on resource-dependent users for a number of reasons including: (i) developing a comprehension of full range of costs and benefits of MPAs, (ii) minimizing the impacts of future MPAs on recreational fishing, and (iii) assuring recreational fishers that their interests are being considered in the MPA planning and management process. The data produced by this study can make an important contribution to any future zoning plan in the GBR region. The current investigation has revealed important and valuable data on the social effects and spatial changes in recreational fishing effort in response to zoning changes in the GBRMP.

Spatial data indicate that recreational fishers in the central and southern GBR redistributed their fishing effort to areas that remain open to fishing. Fishers who lost at least one preferred fishing location to the Zoning Plan generally compensated by shifting their fishing effort to other areas they knew to be good fishing locations, and by finding new areas that they had not exploited previously. Potential implications of these spatial changes in recreational fishing effort for both the GBRMP and recreational fishers include increased likelihood of localized depletions in popular recreational fishing locations and locations that received little exploitation previously. It might also be influenced by reduced quality of recreational fishing experiences through increased crowding and lower catch rates.

Overall, fishers indicated strong support for the general idea of the rezoning of the GBRMP and believed the Zoning Plan would enhance the sustainability of the GBR and the fisheries it supports. However, a significant number of recreational fishers did not believe that their concerns were adequately considered in the rezoning process, resulting in a low level of trust in the GBRMPA among the recreational fishing community. Opposition towards the Zoning Plan expressed publicly by some recreational fishers appears to be due to dissatisfaction with the rezoning and consultation processes rather than dissatisfaction with the outcomes of the Zoning Plan. Additionally, results of this chapter found that a minority of fishers had attended a public meeting or made a submission concerning the rezoning process. Results also highlight the need to better understand the constraints and level of commitment of fishers for participating in public consultation programs.

Spatial information and geographic information tools are mainly used by the GBRMP management agency for gathering public input and informing the public about management decisions. Regardless of the recognised importance and utility of spatial-based information and tools to inform, consult and engage recreational fishers in management, fishers reported a high level of dissatisfaction and distrust with the way spatial information collected in the consultation process was used in the rezoning plan. This might negatively affect the use of mapping-based approach as a public consultation tool in future zoning processes. The use of GIS and other more innovative map-based tools by recreational fishers is still restricted by lack of knowledge or access, inappropriateness of the information provided, and inadequate scale. Besides GPS and chart plotter technologies, recreational fishers prefer to use conventional mapping tools within the scope of their activities.

Results of this chapter exemplify the importance of contextual factors and complex relationships between recreational fishers and the management agency as important constructs in shaping fishers participation and the usefulness of map-based information and related GIS analysis in the consultation about the 2004 rezoning plan of Great Barrier Reef Marine Park.

Finding more specific ways to better incorporate recreational fishers' spatial knowledge and geographic information tools in the management of fisheries and marine protected areas are promising topics for future studies. Theoretical and applied research on fishers' choices and tradeoffs among different substitution strategies is also seen as an important complementary extension of this research. Finally, studies on temporal analysis of spatial changes and shifts in fishing effort in response to changes in management regulations would provide useful information about changes in fishing patterns over time. Further work will also be necessary to explore the potential of 'spillover' effects from protected areas on fisheries catches in areas adjacent to no-take zones.

Chapter 6

ADOPTION OF SPATIAL SENSOR TECHNOLOGY BY COASTAL MANAGERS

Case Study 3 - Linking Science and Management in the Adoption of Sensor Network Technology in the Great Barrier Reef Coast, Australia

Abstract. Wireless sensor network represents the most recent trend for automated intelligent monitoring. In a sensor network, each sensor contains a small computer that is able to interact with other sensors and manage the collection of environmental data. Innovative monitoring techniques such as sensor networks can better support coastal and reef policy decisions and management programs by providing real time data at large spatial and temporal scales. However, while the technology and infrastructure components are now well developed and understood, the useful application of sensor network data and efficient delivery of real time information still needs improvement to better incorporate management needs and priorities. The involvement and collaboration of potential end-users at early stages of the technology development is core a component of the Coastal Environmental Sensor Network in Northeast Queensland. This chapter addresses the extent to which the deployment of sensor networks and the delivery of real time data can best suit managers' and decision makers' needs by providing timely and useful spatial data. It identifies the main drivers and barriers to the deployment of an environmental sensor network along the Great Barrier Reef coast. The chapter concludes by addressing end-users' perceptions about participation in coastal and water quality management processes.

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6.1 Problem Framing – Narrowing the Science-Management Interface

The spatial and temporal scaling of real time data collection is an important factor in understanding dynamic and coastal processes (Collins *et al*., 2006; Kininmonth *et al*., 2004). Emerging technologies such as spatial sensor networks offer opportunities for enhanced monitoring and management of the water resources (Glasgow *et al*., 2004; Kininmonth, 2007). Water quality parameters such as temperature, salinity, chlorophyll, light, nutrients and water flow rates can be remotely measured and collected at large spatial coverage and high temporal resolution in a more cost and time effective manner (Glasgow *et al*., 2004; Porter *et al*., 2005). The monitoring of the physical environment in such detailed resolutions is not currently feasible with existent in situ data logger technology (Chatterjea *et al*., 2006; Kininmonth, 2006; Chatterjea & Havinga, 2009).

High-resolution data collected by the environmental sensor networks (ESNs) provide the opportunity to detect and monitor episodic intensive and previously unobservable events such as changes in sea surface temperature, wave heights flood plumes, and harmful algal blooms (Glasgow *et al.*, 2004; Hart & Martinez, 2006; Porter *et al*., 2005). This is particularly important in remote and hostile environments and in adverse weather conditions where important processes are rarely observed due to inaccessibility and inhospitality (Hart & Martinez, 2006; Rajasegarar *et al*., 2008).

Advancements and applications of sensor networks and remote acquisition go far beyond the aquatic environment including detection and monitoring of air quality, forest fires, earthquake events, and volcanic activities (Hart & Martinez, 2006; Akyildiz *et al*., 2002). Outside the environmental field, applications of different types of sensor networks have included: noise levels measure, air traffic control, traffic surveillance, building and structures monitoring, and health diagnosis (Akyildiz *et al*., 2002; Chong & Kumar, 2003). In spite the overall growing importance of the application of sensor networks to different fields, this chapter will focus on research and policy integration in the monitoring and management of water quality in connected coastal catchments and coral reef systems of northeast Queensland, Australia.

Research and management of coral reef systems, for example, directly benefit from high resolution monitoring of real time data collected by autonomous sensor networks to better understand environmental impacts such as the conditions that lead to coral bleaching events (Chatterjea & Havinga, 2009; Chatterjea *et al*., 2006; Kininmonth *et al*., 2005). The deployment of an array of temperature sensors at different depths of the water column and across a large area can detect changes in water temperature and provide warning alerts assisting the forecasting of conditions that are favorable to coral bleaching (Kininmonth *et al*., 2005). By knowing that the conditions suspected of causing bleaching are favorable; researchers would be able to direct observation and intensify the sampling frequency of the data to be collected by the sensor network (Kininmonth, 2007). In addition real time stream data are necessary to calibrate numerical hydrodynamics models to generate improved predictions.

The Moorea Coral Reef Long Term Ecological Research, in French Polynesia, and the coral reefs of southern Taiwan are examples of advanced implementation of sensor networks in the marine environment (Kininmonth, 2007). In Moorea, the deployment of an extensive undersea wireless sensor network has enabled sophisticated autonomous underwater vehicles to combine with stationary observing platforms to monitor the patterns and consequences of disturbances that arise from or induce long-term trends (Brooks, 2006). In Taiwan, a combination of sensor network and underwater video systems has supported understanding of responses and adaptation of coral reefs to large temporal and spatial fluctuations of seawater temperature, monsoons, tidally-induced upwellings and typhoons (Fan, 2006).

In the Great Barrier Reef (GBR), research priorities and water quality programs stress the need for information and systematic monitoring methods to support policy and management strategies in improving the capability to detect coral bleaching conditions and minimising the continuous decline in the quality of water entering the GBR lagoon from reef catchments (Kininmonth *et al*., 2005; Woodley *et al*., 2006). It is believed that the emerging generation of 'smart' sensors has a great potential for automated intelligent monitoring of marine and coastal systems by providing critical real time information to managers (Chatterjea & Having, 2009, Kininmonth, 2007). Environmental variables collected by the sensor networks can be classified in three categories: current (i.e water temperature at multiple depths, pH, and depth pressure), planned (e.g. light at depth and video), and potential (PAR at depth, UV at depth, C02, PAM fluorometry, turbidity, and nutrients (N,P)) (De Freitas *et al*., 2009). In addition to supporting coral bleaching predictions and calibration of hydrodynamic models, sensor networks deployed at catchments and inshore waters would enable scientists to better understand the complex coastal environmental processes such as increased nutrient loadings and high levels of sediments and pesticides entering the GBR lagoon. For example, if high levels of pollutants (e.g. pesticides) are detected in the GBR, farmers along the coast could be advised to reduce the amount of pesticides that are used (Chatterjea & Havinga, 2009).

Despite current advances and growing implementation of wireless sensor technology (e.g. Brooks, 2006; Fan, 2006), ESNs are not a panacea for all monitoring needs. The deployment of sensors on a scale of a system such as the GBR remains a challenge (Kininmonth *et al*., 2005). Many constraints on the sensor network architecture (e.g. power management, maintenance and usability, standardisation, data quality, security, and transmission) and lack of local expertise still limit the use of the technology from reaching its full potential (Chatterjea & Havinga, 2009; Hart & Martinez, 2006; Kininmonth, 2007; Rajasegarar *et al.*, 2008). Conflicting operational issues related to node failure (e.g. Loh *et al*., 2007); data processing and interpretation (e.g. Collins *et al*., 2006), and information overloads (e.g. Duckham *et al.*, 2007) also contribute to difficulties with automated data collection.

Additionally, there is also the challenge of collecting, processing and delivering the right data at appropriate spatial and temporal scales in a cost and time effective manner and in a useful format that can be used by management (Kininmonth *et al*., 2005; Rajasegarar *et al.*, 2008). Most of the analysis and visualisation of data collected by sensor networks are via GIS-related tools combined with a satellite image and map, and the final products made available via a Web-based interface (Hart & Martinez, 2006). Often, however, scientific data provided by emerging technologies such as sensor networks do not fit the needs or interest of environmental managers and decision makers or it is not presented in a way that can be used in a management framework (Roux *et al*., 2006). From one side, coastal and reef decision (policy) makers are often confronted with the difficult task of gathering and interpreting research findings for use in policy development and implementation. On the other hand, scientists (researchers) face the challenge to address management spatio-temporal scales and to effectively communicate scientific findings.

Although not all research is, or needs to be, focused on policy-relevant questions, adapting research results into usable and applicable information has the potential to improve the impact of research on the management of marine and coastal systems. The use of real time data from reef-based sensor arrays in the GBR has great potential in policy and management decision-making (De Freitas *et al.*, 2009). The deployment of the sensors at the GBR region is intended to be a flexible and responsive process to new knowledge gained by targeting research to management needs; monitoring, evaluation and review, and by continually connecting technological opportunities with current and future management priorities (De Freitas *et al*., 2009).

Participatory design and engagement of coastal managers, from data gathering to information generation, is considered a core component of the deployment and implementation of the environmental sensor networks (ESNs) in the GBR. The successful implementation of the *Coastal Environmental Sensor Network in Northeast Queensland (CESNNQ)* - GBR coast -

project will depend upon how well this innovative technological approach (smart sensors, online delivery and dissemination of real time environmental data, and visualisation of different scenarios) responds to stakeholders' demands, and how well this technology can inform management decisions (De Freitas *et al.*, 2009; Kininmonth, 2007).

The CESNNQ project is an international initiative led by the Australian Institute of Marine Science (AIMS) and James Cook University (JCU). This project seeks to implement sensor network platforms to monitor the GBR coastal environments, and to provide timely and useful data for managers and decision makers. The deployment of systems along the reefs will be complemented by the installation of sensor networks within the estuarine and river systems of the GBR. Data collected will be available to the public via a web interface, the SensorMap (Kininmonth, 2006; Rajasegarar *et al.*, 2008).

This case study addresses some of the contextual related issues involved in making the implementation of cutting edge technologies such as the spatial sensor network technology an efficient and viable reality for the improved management of marine and coastal systems at the GBR scale. Rather than provide a definitive solution for the effective deployment of environmental sensor network, this chapter delineates differences in framing and the socio, institutional and technological dimensions for the implementation and meaningful adoption of wireless sensor network and real time data by potential end-user groups.

Specific Aims

Specifically, this chapter aims to:

(i) investigate to what extent the deployment of geospatial technologies and delivery of real time sensor network data can best suit managers and decision-makers needs by providing timely and useful spatial data, and

(ii) assess the end-users' perceptions about participation in coastal and water quality management processes on the Great Barrier Reef coast.

Current Role of Spatial Technologies in Managing the Great Barrier Reef

Since its establishment in the 1980s and early 1990s, the Great Barrier Reef Marine Park Authority (GBRMPA) has relied on the collection and monitoring of scientific data in the management of the Great Barrier Reef Marine Park (Marine Park) (Lawrence *et al*., 2002). Their research needs have been extensively described, and they include a wide range of biological, ecological, physical, social and economic research needs to support Marine Park management and policymaking (Woodley *et al.*, 2006).

Some of the challenges facing GBRMPA for the conservation of biodiversity and the continuation of reasonable human activity include: ensuring the survival, maintenance and restoration of ecosystem function by managing fisheries and tourism at sustainable levels; reducing the harmful effects of land based activities on inshore waters and habitats to acceptable levels; preventing harmful effects of shipping (groundings, pollution and introduced marine pests); and providing for traditional hunting and fishing while ensuring the conservation of endangered species (Woodley *et al*., 2006). In addition to these existing challenges, there is the rapidly increasing threat posed by global warming to coral reef systems and the industries depending on them. Overall, reef systems need to be as resilient as possible in the face of these challenges. An adaptive management approach, based on good information from monitoring and research, is needed to address these challenges Woodley *et al*. (2006).

The need for autonomous sensors is one of the major problems confronting coral reef researchers managing the GBR region (Reichelt, 2007). The use of technology in the management of the GBR coast has been important since the establishment of the Marine Park in 1975 (e.g., aerial photography for mapping, aerial surveillance for monitoring and enforcement, remote sensing for planning). For instance, the long-term sea temperature monitoring program of the AIMS and GBRMPA uses remote sensing tools, reef-based weather stations, and an array of temperature loggers to determine the effects of global climate change in reefs and coastal systems (GBRMPA, 2007).

The information generated through a Great Barrier Reef Ocean Observation System (GBROOS) has the potential to enhance existing and future monitoring programs, particularly the Marine Water Quality Monitoring Program (Goudkamp, 2006). The Reef Water Quality Protection Plan (RWQPP) is a Federal and State government initiative to improve water quality in the Great Barrier Reef. This management initiative aims to halt and reverse the decline in water quality within 10 years by reducing the runoff of diffuse sources of pollutants entering the reef;

rehabilitating and conserving areas of the GBR catchment that have a role in removing water-borne pollutants (Goudkamp, 2006; Haynes & Prange, 2007).

The integrated monitoring program to assess water quality and ecosystem status in the Great Barrier Reef World Heritage Area (GBRWHA) is composed of several components: marine water quality flood monitoring, inshore marine water quality monitoring, inshore marine water pesticide monitoring, remote sensing of GBR wide water quality, inshore coral reef monitoring, and intertidal seagrass monitoring (Haynes & Prange, 2007). ReefTemp is another example of how technology is supporting the management of the GBR. ReefTemp is a remote sensing tool which provides high-resolution sea surface temperature mapping information on coral bleaching risk for the GBR region (GBRMPA, 2007). These programs are expected to become increasingly reliant on remotely sensed data from satellites as well as on the use of robust and accurate water quality sensors with long term data logging capacity (Goudkamp, 2006).

What are Wireless Sensor Networks?

Wireless sensor networks represent the most recent trend in emerging spatial technologies for automated intelligent monitoring (Kininmonth *et al*., 2005; Rajasegarar *et al*., 2008). The sensors are typically made up of hundreds or even thousands of tiny energy-efficient, battery operated sensor nodes with built-in wireless transceivers, and computer components (e.g. CPU, small amount of RAM) (Chatterjea *et al.*, 2006).

Environmental sensor networks evolved from automated loggers that recorded data at specific intervals and required manual downloading by a maintenance team (Hart & Martinez, 2006). The wireless sensor nodes collect data autonomously and a data network is usually used to pass data to one or more base stations, which forward it to a sensor network server (Chatterjea *et al*., 2006; Hart & Martinez, 2006). In the land-based network server, high-resolution data streams are stored in a database, processed and made available to the end-users via a web interface (Fig. 6.1).

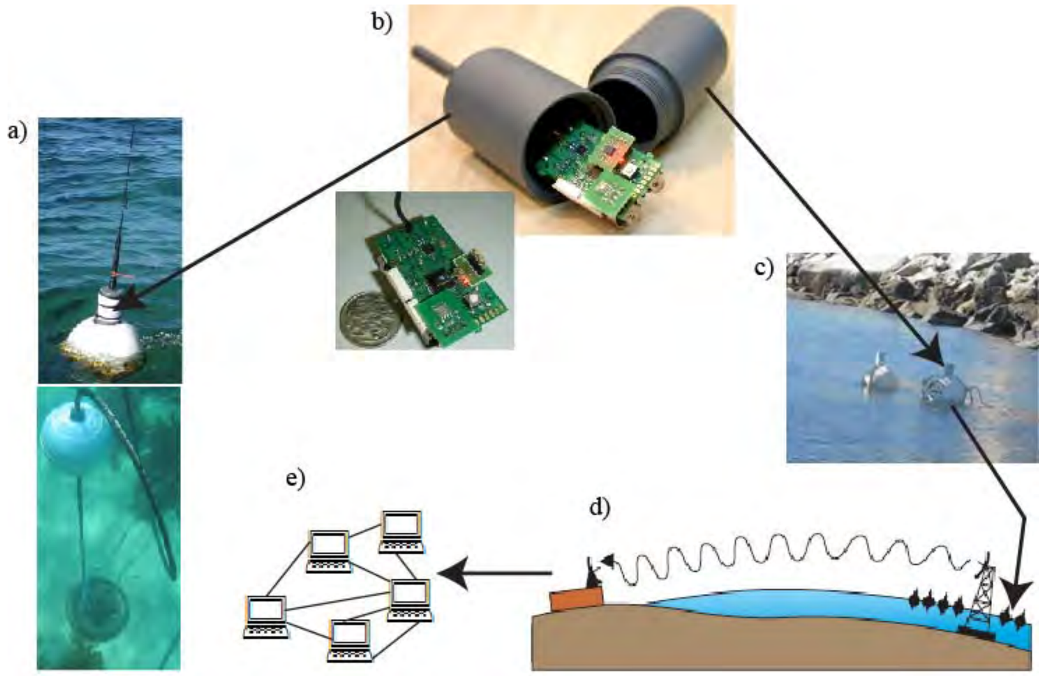

Figure 6.1. Schematic diagram of data collection, process and deliver of a sensor network. a) surface and underwater views of deployed sensors floating at Townsville coastal waters (Nelly Bay, Magnetic Island, GBR Australia), b) protection against the ocean conditions requires the customised machining of robust canisters and detail of miniature computers used to capture and transmit the environmental data, c) sensor network deployed on buoys floating on reef, d) communications tower connected to sink node, collects data from sensor network and transmit it to AIMS through microwave radio transmissions, and e) deliver to end-users via web interface.

In a sensor network, each sensor contains a small computer that is able to interact with other sensors and manage the collection of environmental data. They are called ‘smart’ sensors because they can be controlled and programmed to adapt to a pre-set condition (such as temperature threshold or event detection) and sampling frequency from the central land-based control system (Kininmonth *et al.*, 2005).

In contrast to other sensors with wireless transmitters, wireless sensor nodes are able to process the data within them before transmitting the sampled data due to their built-in computational capabilities (Chatterjea *et al.*, 2006). In this case, if a sensor node presents a default reading, the sensor is able to stop the message instead of wasting energy transmitting it. The surrounding sensors are informed about the default problem so the transmission process is optimised. Additionally, instead of transmitting data directly from a sensor node to the final destination in the base station, data from a sensor node can be relayed through a number of intermediate sensor nodes. The nodes are also deployed at various depths using floating buoys. Such characteristics enable the network to cover a much larger geographical area (Chatterjea *et al.*, 2006; Kininmonth *et al.*, 2005).

Case Study Context

The study area of this chapter covered parts of the north (Townsville) and south (Gladstone) sections of the GBR (Fig. 6.2). The studied region presents a geographic diversity encompassing a range of geomorphologic features (e.g. inter-reef areas, continental slopes) and diverse physical conditions (e.g. temperature regimes, current influence, water quality and weather) (Hopley *et al*., 2007; Kininmonth *et al.*, 2004). The scale of the fluctuations of the environmental processes, across the GBR region, ranges from kilometer-wide oceanic mixing to millimeter-scale inter-skeletal currents (Kininmonth *et al.*, 2004). In this context, a strategic collection of data at appropriate temporal and spatial scales is critical for effective environmental monitoring and analysis. Currently, a pilot network has been tested across an area of 400 km of the GBR in the Townville coast region covering Magnetic Island, Orpheus Island, Davies Reef, and Heron Island (Fig. 6.2).

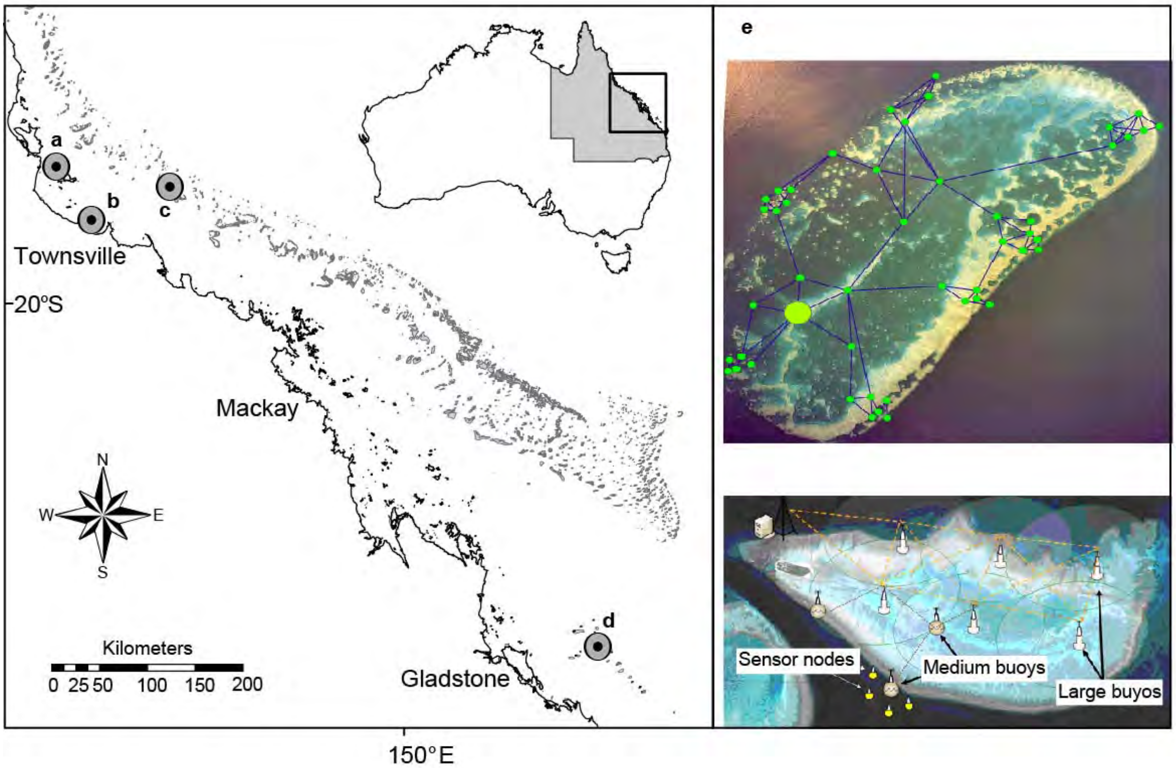

Figure 6.2. Sensor network pilot sites (◉): a) Orpheus Island, b) Magnetic Island, c) Davies Reef, d) Heron Island, and planned network designs for the GBR (e).

Small networks, deployed at Nelly Bay (Magnetic Island) and Davies Reef are collecting information which will support research into the thermal structure of the reef crest as well as the mechanical design of sensor buoys (Kininmonth, 2006). In addition, the upgrade of data transfer linkages is also underway and will permit video streaming of the reef activity along with sensor measurements (Kininmonth, 2007).

The high-resolution data stream provided by the sensor network will include data on multiple wider spatio-temporal scales, complementing the current data logging technology, which only allows single point measurements. However, some technical barriers including fouling, powering equipment, maintenance of equipment in remote areas, and radio transmission range still need to be overcome (Hart & Martinez, 2006). Other overall challenges to be addressed in the process of the implementation and adoption of sensor networks data include integration of the data into modeling, visualisation systems, ability to manage and maintain a system, and the provision of timely and useful information for management purposes (Kininmonth *et al.,* 2004).

Particular challenges to the deployment of a sensor network in a complex and harsh environment such as the GBR include the design and connectivity with a reliable network, that copes with tides, currents and tropical storms, and the transmission of data over large distances through a microwave communication system (Chatterjea *et al.,* 2006; Rajasegarar *et al.,* 2008). Cables that fix the floating buoys containing the sensor nodes to the ocean floor have to resist rough hydrodynamic conditions. In addition, sensor nodes deployed at distant reefs such as Davies Reefs (Fig. 6.2c), for instance, face the problem of maintaining the connectivity between the nodes during operation because of the movement of antennas caused by ocean wave dynamics (Rajasegarar *et al.,* 2008). In this situation, the transmission of the collected data through a microwave communication system from a tower installed on Davies Reef to the AIMS research facility 80 km away is constrained by limited battery power required to establish communication between the nodes (Chatterjea *et al*., 2006).

Despite such challenges, there is great expectation and support of researchers and managers for environmental monitoring with small distributed wireless sensor computers in the GBR (De Freitas *et al*., 2009). A growing body of publications in the areas of software and hardware design and field operations, combined with collaborative associations (e.g. Coral Reef Environmental Network) and academic facilities (e.g. ARC Research Network on Intelligent Sensors), have represented an essential mechanism to address the technical challenges by providing experience in installations and operation of sensor networks in the marine environment (Kininmonth, 2007).

6.2 Methodological Approach

Workshops, short online surveys, and one-on-one interviews were the main data collection methods. Such approaches, particularly workshops are commonly used in studies investigating the linkages between managers and researchers in order to reconcile the provision of scientific information with user demands (e.g., Borowski & Hare 2007; Jacobs *et al.*, 2005; McNie, 2007; Totlandsdal *et al.*, 2007).

The population of this case study was composed of representatives of science, management and natural-water quality non-profit conservation organisations. Participants were selected deliberately to cover a wide range of expertise, including decision makers for water and coastal issues, spatial technology experts, water quality researchers, and non-profit organisation project coordinators.

Data Collection

Workshops

The overall aim of the workshops was to provide a venue for scientists and managers to interact, while introducing the adaptive implementation sensor network project and addressing the dissemination of real time spatial information. Specific goals of the workshops included: (1) increased participant understanding of new technologies like the sensor network, (2) participant comprehension of interactive tools to manage new technologies, and (3) facilitated discussion on the application of sensor network data for the work environment. Some of the specific tasks of the workshops sought to identify compelling questions (such as spatio-temporal scales) that would require new types of sensors or new strategies for the deployment of wireless technologies for inshore water quality, to specify the impediments (constraints) to the application of the sensor network to management and policy decision-making, and to delineate responsibilities for the interpretation and dissemination of the real time data provided by the sensor network to end-users.

To identify the compelling questions requiring sensor network data, participants of the workshops were divided in groups and asked to identify the top five priorities management and research questions or issues that needed wireless sensor network data. A summary matrix (Fig. 6.3) was provided to the different groups so they could discuss and write on the matrix. For each management/research priority, participants were asked to specify requirements (needs/conditions) and limitations (barriers/constraints), spatial (local to global) and temporal (current to future) scales, and the information delivery tools required for an effective use of sensor network data. Requirements and limitations were grouped as technical (related to infrastructure and other physical aspects of the sensors) and organisational-institutional (related to the adoption and implementation aspects of the sensors). For instance, issues related to reliability, accuracy and design were grouped as technical, while endorsement of standards, confidence in data, and lack of integration across skills/institutions were identified as organisational-institutional. The matrices were discussed in a plenary session and compiled by the facilitators of the workshop. The summarised data were used to develop a conceptual typology integrating the requirements and limitations of deploying a sensor network in the GBR across a spatio-temporal scale.

	Requirement (R) / Limitations (L)									**Information delivery tool/mechanism**
	Technical					Organisational/Institutional				
	(L) power efficient, reduced battery drain, very much cheaper, biofouling					(R) Real time monitoring of data stream,; Public exposure of data				
Management-Research Questions/Priorities (near-, mid-, and long-term needs)										
[EXAMPLE]: Detailed hydrodynamic models of reef circulation	C - 2					I - 1				Online graphic data

Spatial-temporal scale

[Please fill the boxes with the proposed symbols below. You can also include additional symbols to fit your needs.]

Temporal	*Spatial*
Current (now)= C	Local= 1
Immediate (1year)= I	Regional= 2
Projected (3-5 Years)= P	National= 3
Future (>5Years)= F	Global= 4

Figure 6.3. Summary matrix used at the workshops to identify requirements and limitations for the adoption of sensor network and effective use of real-time data.

The results of the workshops were recorded formally in two reports (De Freitas, 2006; De Freitas 2007). A feedback cycle allowed the participants to review the drafts of both workshops and to comment and make corrections they thought were necessary. This phase aimed to reduce misinterpretations and to improve accuracy of the data collected in the workshops.

The first workshop (*The Adoption of Sensor Network by Coastal Managers: A Marine Focus Approach*) was held on the 5th of December, 2006 at the AIMS, and focused on the marine environment. The second workshop (*The Adoption of Sensor Network by Coastal Managers: An Inshore Water Quality Approach*), held on the 26th of July at the Department of Primary Industries and Fisheries (DIP & F), focused on the use of sensor networks for inshore water quality issues. Both workshops were held in Townsville and they were conducted with the support of an experienced facilitator. Stakeholder representatives were selected specifically to represent a wide range of expertise, including water and coastal decision makers, spatial technology experts, and water quality researchers. The workshop was structured as a combination of short research presentations, invited guest speakers and interactive breakout group discussion sessions. The mix of short (15 min) keynote presentations (Table 6.1) covered various technological, scientific and management aspects of the adoption of sensor network technology.

Table 6.1. Overview of presentations of the first and second workshops.

1st WORKSHOP	
Presentation	**Speaker - Institution**
1. The Sensor Network & Overview of Demos	Stuart Kininmonth - AIMS & Ian Atkinson - JCU
2. Digital Moorea – Moorea WetNet	Andrew J. Brooks - Moorea Coral Reef LTER,USA
3. Possible uses of sensor network in Long-Term Ecological Research at Kenting Coral Reefs in southern Taiwan	Tung-Yung Fan - National Museum of Marine Biology and Aquarium, Taiwan
4. Interfaces of science and management	Simon Woodley - Environmental Consultant, S & J Woodley Pty Ltd
5. The utilisation of new technologies and spatial in coastal management & WebGIS Demos	Debora De Freitas - JCU
6. GBRMPA's Research and Monitoring Needs & GBROSS	Katrina Goudkamp - GBRMPA
2nd WORKSHOP	
1. Science, management & real time data in the GBR: An Inshore Water Quality Approach'	Debora De Freitas - JCU
2. International Perspective on Coastal Sensor Network and the Current Status of the Sensor Network Implementation on a Fringing Coral Reef on Australia's Great Barrier Reef	Stuart Kininmonth - AIMS
3. Management drivers for remote sensing and data acquisition and logging at inshore coral reef systems of the GBR	David Haynes & Joelle Prange - GBRMPA
4. Does increased river suspended sediment load increase GBR lagoon regional turbidity: use of continuous turbidity loggers	Jon Brodie – ACTFR & MTSRF
5. Deployment of Wireless Sensor Network in the Queensland's Burdekin Irrigation Area	Matthew Dunbabin – CSIRO ICT Centre
6. Tropical Terrestrial HUB	George Lukacs - ACTFR

Short online surveys

The online survey was designed through a web-based tool developed by SurveyMonkey.com, SurveyMonkey.com Corporation (Finley, 1999). The survey web link was sent by email to all participants that had confirmed attendance to the workshops. The short questionnaire was circulated two weeks prior to the workshop allowing participants to identify priority themes that would drive the preparation of the workshops' agendas and provide starting points for the in-depth discussion sessions (Table 6.2).

Table 6.2. Pre-workshop online questions provided to the participants of the second workshop.

Question 1	Briefly state your opinion about the following statements: • 'Scientific data provided by new technologies often does not fit the needs or interest of policy-makers and environmental managers or they are not presented in a way that can be used in a management context'. • Improved communication between scientists and managers/policy-makers is a demand frequently brought up when Science-Policy interface is discussed. Who should be responsible for this improvement? Why?
Question 2	List up to 3 environmental variables (e.g. water temperature, pressure at depth, turbidity, nutrients) you need to be delivered by sensor network technology.
Question 3	Please indicate the extent to which you agree or disagree with each of the following issues: a) Real time data allow decision-makers to make timely and better informed decisions. b) Information overload can be a problem for both decision makers and researchers. c) Storage and availability of data provided by technologies such as sensors network are of responsibility of data producers. d) Data provided by sensor network should be public available. e) Information for environmental management must be driven by management needs. f) Coastal/environmental managers need faster and easier access to the data as its being collected.
Question 4	Please, identify three issues/topics you would like to be addressed at the Workshop.

The feedback from the online questionnaire represented an important input into the preparation of the agenda and structure of the workshops. The questions were not intended to be comprehensive but rather to support the identification of priority themes to be addressed by the breakout groups in in-depth discussion sessions. It allowed the design of more purposive and interactive activities that were more responsive to participants' interests and expectations. For instance, divergent answers expressed by technology developers (including researchers) and coastal managers in question 1 (Table 6.2) influenced the design of the breakout discussion session groups to include at least 1 representative from sensor development and 1 from the management side. In addition, answers of question 4 also guided the content to be addressed by the keynote presentations.

Interviews

A total of 10 participants (five environmental/coastal managers, three researchers, and two IT/GIS experts), out of the 32 invitees who had participated in at least one workshop, were subsequently interviewed. The interviews aimed to investigate in depth some key issues addressed during the workshops (see Appendix D) [1]. Time and work schedules were the main difficulties cited by the participants who were not available for the interview phase.

The semi-structured interviews were conducted mainly face-to-face, but in two cases, because of distance constraints, participants were interviewed by telephone. The interviews, carried out from March to May 2007, lasted on average about 45 minutes.

Data Analyses

As in Chapter 4, data in this chapter were analysed qualitatively by coding processes and exploratory descriptive statistics. Selected quotations are also used to provide evidence and illustrate themes and patterns that emerged in the analysis.

‘A priori-coding’ list was derived from the questions of the interview protocol and issues that emerged from the workshops. This initial list of codes allowed the organisation of the data into meaningful categories. For example, to address the extent to which the deployment of a sensor network and delivery of real time spatial data can best meet end-users’ needs, collected data were categorised as benefits and constraints of adopting sensor networks, technical and organisational aspects, research and management questions, and delivery tools and mechanisms constituted initial categories of codes.

In the ‘post-coding’ phase, detailed codes were developed by analysing the notes of the workshops and the transcriptions of face-to-face interviews. Additional codes were developed and the initial coding scheme was revised and refined subcategories developed. For instance, requirements (e.g. ability to determine long-term trends, cheap sensor) and limitations (e.g. long distance for radio transmission, lack of casual-effect models) emerged as important categories under the initial code ‘technical and organisational aspects’ related to of sensor network

[1] Appendices are in Volume 2 of this thesis.

deployment. This structure was the foundation for the development of a conceptual typology integrating subcategories identified in requirements and limitations in a spatio-temporal scale defined for the project. Likewise, water quality (e.g. relationship between suspended sediments and turbidity) and data integrity (e.g. quality assurance/control) were identified distinct categories under ‘compelling research and management questions’ to be addressed by a sensor network deployed along the GBR coast.

In addition, standard exploratory descriptive statistics, conducted with SPSS version 15.0 for Windows, were used when necessary to explain overall quantitative trends in selected variables. For instance, frequency distributions were used to assess the level of level of agreement (5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree) with a series of 8 statements about public participation in coastal and water quality management processes in the GBR. Similarly, a graphic of frequency distribution was used to represent the level of priority (low, medium, high) to list of current, planned and potential variables measured by the sensor network within the context of the project ‘Coastal Environmental Sensor Network in Northeast Queensland’. Further statistical analysis was constrained by the small sample size and purposive selection of the participants.

6.3 Results

Research information to support reef and coastal policy decisions and management programs needs to address current and emerging issues, to detect trends in key aquatic system variables, and to help evaluate effectiveness of management strategies. The deployment of a wireless sensor network and the dissemination of real time data for the GBR is intended to be a flexible and responsive process to generate new information by targeting research to management needs; monitoring, evaluation and review, and by continually connecting technological opportunities with current and future management priorities (Kininmonth *et al.*, 2005). A balance between the supply and demand for real time data in managing the GBR system needs to be addressed. Therefore, understanding the need and expectations of the potential users of information is highly relevant to comprehend the context in which decisions are made (Woodley, 2006; Slob *et al*., 2007).

The two workshops included 32 participants from environmental and water quality management (15), research (8), information technology (8), and a non-profit organisation (1) fields. Local and regional non-government organisations were also invited but they were not represented in both workshops. In total, the workshop sessions and in-depth interviews yielded over 30 topics, 20 compelling research questions/issues, 21 requirements and 13 limitations on how, when, and why sensor network real time data may or may not support research and management priorities. Nevertheless, it cannot be assumed that either the set of the questions is exhaustive, or that all research and management issues for the deployment of sensor network have been highlighted.

Compelling research and management issues

A follow-up phase rated the priority levels of a set of management issues previously identified by the first workshop. Key informants were asked to identify the relevance of the topics provided to their research and management decision-making contexts. Climate change was the most relevant topic for 90% of the respondents, followed by coral bleaching (80%), sediment and nutrient management (e.g. map flood plumes) with 80%, and risk areas (e.g. oil/chemical spills around major ports) with 70% of the answers. Long-term changes in ocean temperature, compliance and enforcement (e.g. preservation zones) and wildlife studies (e.g. influence of changes sea surface temperature and seabird feeding; beach sand temperature and turtle nesting) were categorised as relevant by 60% of the respondents. Other less relevant issues included: ground truth hydrodynamic models of reef circulation (50%), biological census data (30%), and education resources (e.g. web links to live video cameras at reefs) (30%).

Additionally, throughout roundtable discussion sessions, participants envisioned a number of principles, organisational-technical requirements and information and communication channels about the adaptive deployment of ESNs in the GBR coastal zone (Table 6.3). This initial set of principles, management and technical issues provided the basis for and guided more in-depth discussions to be addressed in the second workshop.

Table 6.3. Initial set of topics addressed in the first workshop.

General Principles	Organisational and Technical issues
• measurable variables x desirable variables • effect of real time data access on management thinking and responses • rising expectations in both managers and public • information overload, interpretability and accessibility • bi-directional communication • temporal-spatial scale (e.g. amplitude, spatial disposition, sampling frequency, adaptive sampling scheme) • field deployment problems: technical (e.g. loss of instruments), environmental (e.g. topography), socio-cultural (e.g. vandalism) • adaptive sampling scheme • sensor network perceived as a science-driven initiative	• measurement of non-normal parameters • ground truth • real time measurement develop of response • fine temporal measurements • technical-infrastructure and operational skills requirements • intellectual property rights • cost and reliability (how can it be avoid?) • fouling • accurate meta-data • efficient power usage and high bandwidth • data transmission • hardware and software interoperability
Management issues	**Dissemination channels**
• climate change and coral bleaching • long-term changes in ocean temperature • biological census data • hydrodynamic models of reef circulation • sediment and nutrient solution • real time information from high risk areas (e.g. ports, shipping channels) • compliance enforcement at high risk areas (preservation zones) • wildlife studies (e.g. influence of changes sea surface temperature and seabird feeding, beach sand temperature and turtle nesting)	• international court proceedings • online graphic data and data stream • real time video of remote locations as educational tool • 3D visualisation programs • scaleable visualisation • reports, alerts (e-mails, SMS)

The compelling questions that require new types of sensors or new strategies for deployment of wireless technologies for marine water quality and coral reef monitoring can be summarised in these main categories: water quality, climate change, connectivity and other issues (Table 6.4).

Table 6.4. Example of compelling research questions relevant to the GBR Ocean Observation System (GBROOS).

Water Quality	Climate Change
• How can monitoring of water quality characteristics (including sediments and nutrients) be automated (e.g. development of robust data loggers) for use in Reef Water Quality Protection Plan (RWQPP)?	• What long-term changes are likely to occur in coral reef systems as a result of climate change?
• What GBRMP areas have high environmental value and are subject to pollutant inputs (e.g. hydrodynamic modeling, risk assessment/decision support systems)?	• What are the key factors that lead to bleaching and how can these be predicted?
• How can hydrodynamic models of GBR water circulation be used to ensure optimal location of water sampling?	• What are the likely impacts of climate change on local and regional hydrodynamics?
Connectivity	**Other (Water quality, shipping – oil/chemical spills)**
• What are the effects of GBRMP zoning on dispersal and supply of larval fish and benthic organisms (including corals)?	• What are the relationships between catchment processes, pollutant loads delivered to the marine park, and the impacts of the nearshore marine environment?
• What are the consequences of large-scale processes (e.g. hydrodynamics and reef connectivity) for management strategies (e.g. application of patterns of reef connectivity to the design of marine protected areas, and what are the key knowledge gaps in large-scale processes?	• What are pollutant tolerances for coral reef and seagrass ecosystems for temperature, salinity, nutrients (NOx), suspended solids, antifoulants, dispersants and pesticides/herbicides?
• What factors can cause changes in local and regional connectivity and what are the implications of these, both for biodiversity and GBR-dependent industries?	• Which sites are of particular natural and cultural value for protection during acute incidents such as oil spills?

An online forum (www.coastalzone.net) provided an additional discussion platform for workshop participants and other interested parties to interact and discuss issues relevant to the adoption of the sensor network. However, the participation rate in the forum was considered low with just 29.4% of the workshop attendees contributing to the online discussion between the first workshop conducted on December 2006 and the second workshop on July 2007. Both researchers and environmental managers argued that they don’t have enough time to participate in online discussions, and that they are already overwhelmed with lots of information. It seemed that although more time consuming, they still prefer face-to-face meetings. Reasons why researchers and managers do not respond to web tools could include, but are not limited to busy work schedules and meetings, and to the preference to other form of contact such as telephone and email.

Therefore, efforts were directed towards a second workshop connecting the need and adoption of sensor network data within an inshore water quality focus. The second workshop aimed not only to more deeply explore the issues identified in the first workshop, but also focus on the information and management needs within a catchment-to-coast perspective. Attendees of the second workshop were composed of six (6) water quality managers, two (2) coastal-water quality researchers, four (4) information technology-GIS experts, and one (1) representative of a local non-government organisation.

Prior to the workshop, the attendees had the opportunity to shape the workshop dynamics by participating in a short online questionnaire containing closed and open-ended questions. Overall, the online survey identified that the potential users of the ESNs believe that:

- overly technical information delivered to non-technical decision makers does not enable management to see the benefit of new technologies;
- leading edge technology is developed from an engineering perspective and it takes time and work to mesh this with real world needs;
- both parties bear some responsibility for improving communication between scientists, and managers and policy-makers. Policy makers need to make their needs clear to scientists and scientists need to let policy makers know what type of science they are doing, what are the new innovations and what might be of interest to policy-and decision makers;
- the three environmental variables needed to be delivered by sensor network technology can be categorised in three groups: 1) turbidity; 2) nutrients, temperature, and photosynthetically active radiation (PAR); and 3) chlorophyll, light, and water flow rates;
- relevant issues to be addressed by the workshops would include: cost-benefit of the sensory network over conventional monitoring and community involvement; conversion of information from sensor network into management outcomes; data format needs; decision-making workflow: how does or should sensor data be used?; sensor density and affordability; correlation between real time fine temporal scale and temporally long term biological processes; accuracy and calibration of sensors; biofouling; and reliability.

The general questions and core issues that should be addressed by sensor network technology in the inshore/nearshore water quality context were grouped into three main categories (Table 6.5).

Table 6.5. Clusters of compelling questions and issues that require wireless technologies for inshore/nearshore water quality.

Water Quality
• Is there a relationship between suspended sediments (rivers) and turbidity (reef)?
• Is there any correlation between suspended sediments and Photosynthetically Active Radiation (PAR)?
• What is the relationship between water chemistry and water quality?
• What are the nutrient concentrations (real time-) of the water body?
• Can production and turbidity be measured in a spatial-temporal scale?
Data Integrity
• Quality assurance/Quality control of sensor data, sensor network integrity.
• E.M.S. (satellite) data validation (particularly Chlorophylla and Turbidity).
Other
• Explore the covariance of variables that may affect water quality, e.g. wind vs. turbidity, boat traffic vs. turbidity.
• Knowledge of system (finer-scale).
• Biofouling

Requirements and Limitations for the adoption of sensor network in the GBR

Data collected throughout the workshops led to the development of a *Spatio-Temporal Conceptual Typology,* which identified the spatial and temporal scales of the requirements and limitations for the adoption of sensor network technology and real time data were identified within a spatial-temporal scale (Fig. 6.4a-b). The scheme presented in Figure 6.4 was not distinguished by management issues or by the participants' field (e.g. technology developer, researcher, or environmental manager). Rather, it presents an integrated view of the joint understand of these three stakeholder groups. A detailed list of requirements and limitations for specific management issues can be found in Appendix D.

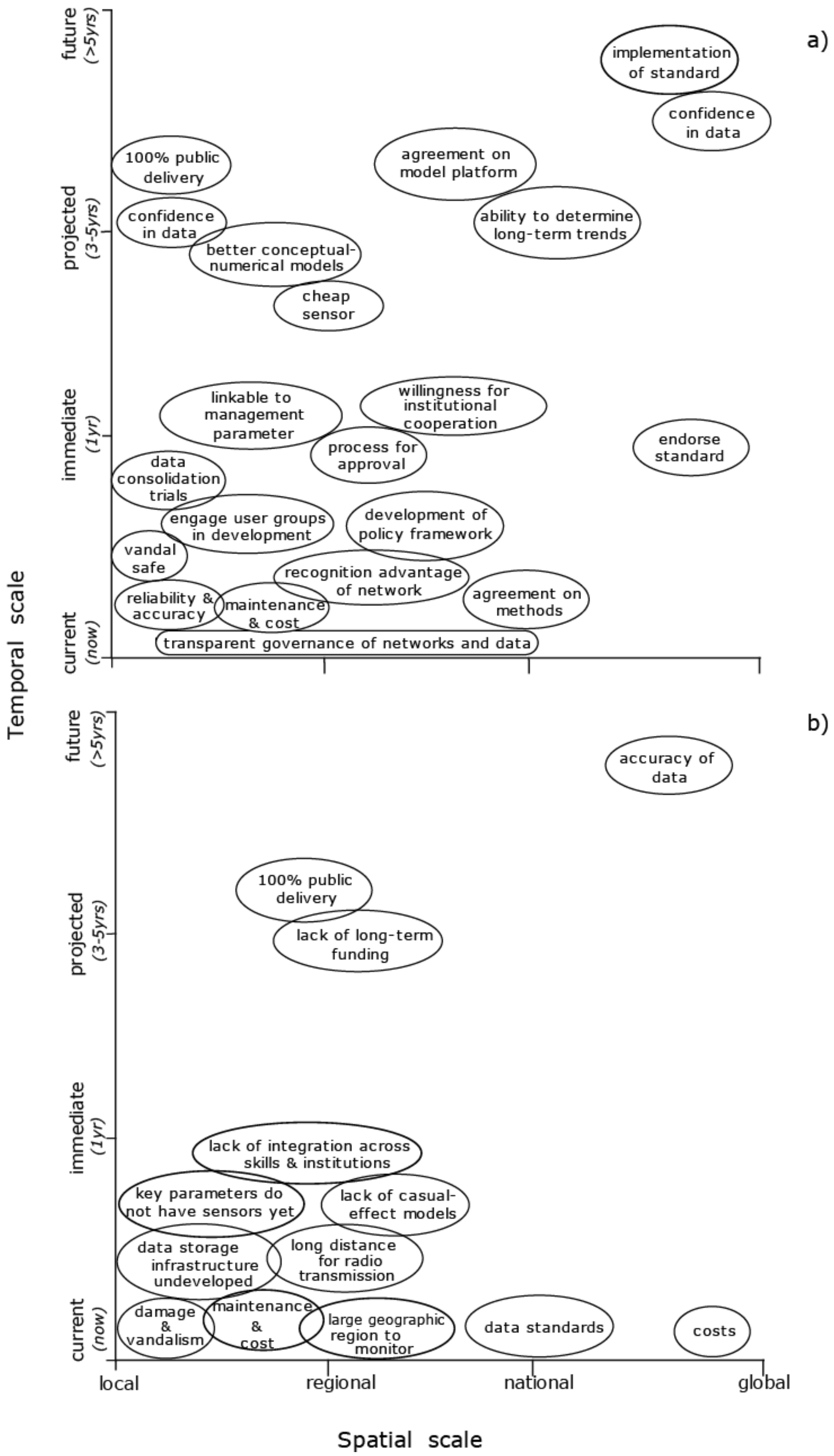

Figure 6.4. Conceptual scheme of spatio-temporal scale of **requirements (a)** and **limitations (b)** for the adoption of sensor network data and technology

The schemes show that, overall, both requirements and limitations are concentrated at local and regional spatial scales and within a current or immediate temporal scale. Such distribution corroborates previous discussions taken in the first workshop held on 5th December 2006. The participants detailed the reasons behind their selection of the requirements and limitations during the interview phase. The potential benefits of the adoption of sensor technology and real time spatial data supported the requirements selected, while the limitations were based on the current and potential constraints on its use and dissemination. Their selections were also based on their vision of the sensor network project, as reported by one of the interviewees:

> *"the sensor's project is composed of three main components: one is sort of an infrastructural part; the other is a research part, and the third part is the end-user products".*

Overall, interviewees were highly supportive about the idea of a deployment of sensor network, although some were skeptical about the geographic extension of the sensors' distribution and the real need for this sort of technology. The applicability of the collected data to the end-users was another criteria considered to define the requirements for the adoption of the sensor network and its real time data. The information collected needs to be timely, relevant and in a useable form properly understood by managers, decision makers, and other end-users so they can understand it properly. Costs, although they are important, were not considered a major criterion, because it was believed that costs of deployment, collection and processing of data would not be expected to be higher than the usual costs, including human time and boat trips, of physically collecting data in remote areas of the reef systems.

Other important factors in the selection of the requirements presented in the diagram (Fig. 6.4a) were the current needs and the potential benefits of the sensor network in supporting future decisions (which means decisions not able to be made now because of the lack of technology and data). Among the most commonly reported needs and potential benefits were: i) measurement of parameters linked to a management problem, ii) calibration of remote sensing and data loggers, iii) higher temporal and spatial resolution, iv) climate change temperature and bleaching events – identification of reefs' hotspots, v) water circulation patterns in the coastal system, and vi) monitoring of specific events such as sediment at rainfall periods. The sensor network technology is also expected to be able to support research and management of underwater sounds like marine mammals, ships and boats.

A list of criteria was provided to identify the limitations (Fig.6.4b) of the use of sensor network technology. For example, data standards mainly related to ownership, storage, and management were identified as a major challenge limiting data handling and dissemination. Participants also reported the problem that institutions tend to hold the information for long periods of time while developing papers and reports. Another potential impediment identified by some of the interviewees was the capacity of the sensor network technology to provide practical ‘usable and purposive data’. For instance, a workshop’s participant stated that:

> *“People will not take up anything new unless it's really demonstrated that it's something that they can use straight away”.*

Another participant highlighted that:

> *“One of the concerns I have about this sort of technology is that you can collect data relatively easily, so you collect data for no purpose. So much monitoring in the past has just been done with no purpose, it was just collecting data”.*

In this sense, the two workshops have provided a list of key compelling research and management questions and topics (see Tables 4 and 5) that participants believed to be essential to be supported by sensor network technology.

Another limitation is the fact that ‘key parameters do not have sensors yet’. The interview and online survey respondents were asked to rate their levels of priority to list of current, planned and potential variables measured by a sensor network (Fig. 6.5 a-c). By current it is meant that the sensors can measure it now, while planned means that the technology has the capacity to measure but has not been tested at the present time; and by potential it is meant that further technological and infrastructure improvements needs to be made to enable measurements of this particular variable.

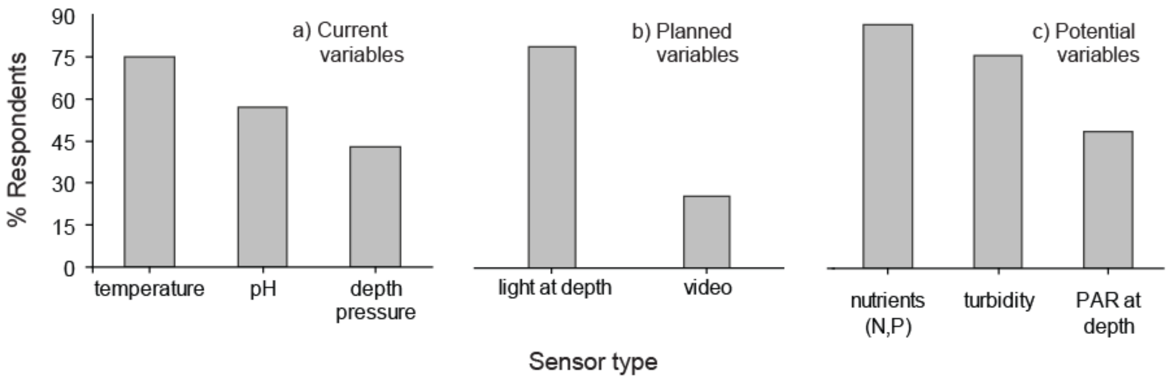

Figure 6.5. Variables measurable by the wireless environmental sensor network.

The highest ranked variable of interest was nutrients (nitrogen, phosphorus) with 88.9% of the responses, followed by turbidity (77.8%), light at depth (77.8%), and temperature (75%) (Fig. 6.5c). Of those top-four variables, only the temperature can be measured now. The other three are either in the potential (nutrients and turbidity) or planned (light at depth) design phases. However such findings might be biased because participants (mainly from environmental management backgrounds) expressed a high degree of uncertainty about what the variables are and what information their measurement can provide. During the interviews, questions such as *“What is depth pressure? ... it would give you just depth profiles?”; “What's PAR again? Ah, it is photosynthetic active radiation, now I got a little bit confused too because you have light there and turbidity.”; “Light at depth would be the same thing as measuring turbidity for me. That would interest me. Chlorophyll doesn't show up at all.”* were quite common.

The potential constraints to using sensor networks go far deeper and include: i) lack of long-term investment, ii) reliability – level of uncertainty in technology measurements; iii) scalability – it is difficult to scale the application over a large area and to orient it physically towards what happens in the natural environment; iv) misinterpretation of data provided - the provision of massive amounts of raw data could be interpreted erroneously by different users; v) information overload – data provided in an unprocessed form could be useless and overwhelm end-users.

The collection and dissemination of real time data needs to be fitted in a well-established purpose and defined context, and the technology has to be functional at a regional scale. Data provided by geospatial technologies such as the sensor network needs to be supported by adequate mechanisms for information delivery. The workshop participants stated that such delivery mechanisms needs to:

- develop a dissemination information plan for the end user;
- establish a system of easy integration of data;
- address liability and data sharing issues (e.g. Who owns the data and how to use it? How will the sensor data will be processed and aggregated?);
- incorporate scalability questions, and
- develop a collaborative user-friendly web platform for data diffusion

Overall, participants of the workshop expressed substantial concerns, for instance, about scientific and political risks of providing raw datasets of real time data freely available on the web. Access by different users might result in different interpretations of the same data which may cause political concern. How public is the data, and how is the public able to access the data which have been collected using public money by research and government institutions? This is a highly sensitive and important issue that will be addressed in the next section.

Spatial Distribution of the sensors

The selection of sites for the deployment of sensors faces the following types of challenges: i) physical (e.g. fouling, powering, visual pollution); ii) infrastructural (e.g. radio transmission range, manage large amounts of data); and iii) meeting both research and management priorities. Therefore, it is necessary to identify, and if possible achieve a consensus, about where information suppliers are planning to deploy the sensor devices.

During the interviews, key informant participants were provided with a list of 37 sites (e.g. Nelly Bay, Davies Reef, Heron Island) located within the GBR region provided by the GBRMPA. Out of those 37, just six sites (Lizard Island, Heron Island, Orpheus Island, Morton Bay, One Tree Island, and Myrmidon Reef) were common to both the sensor networks initiative and the actual temperature loggers of the water quality program of the GBRMPA. Participants were asked their opinion about the sites list and also to report any other relevant places they would like to be included in the sensor network initiative.

The need to increase the temporal and spatial resolution of the sensor network was strongly supported by the environmental management bodies, particularly to support water quality monitoring programs. Overall, all sites described in the list were considered relevant by researchers and managers. Additional places would include mainly inshore and middle reefs, for instance: Florence Bay (Magnetic Island), Dingo Beach fringing reef, Brook Inlands, Kelso Reef, Middle Reef, river and catchment mouths (Burdekin, Tully, Herbert, and Fitzroy).

Public engagement in technology development

End-user participation and adoption of real time data is the cornerstone of the adaptive approach of the sensor network initiative. A series of closed-ended statements and open questions were conducted with key informant participants as an attempt to identify the intended public of the sensor network and to understand participants' beliefs and attitudes towards public participation processes. Interview and online survey respondents were asked to rate their level of agreement (on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree) with a series of statements about public participation in coastal and water quality management processes (Table 6.6).

Table 6.6. Respondents' level of agreement with statements about statements about public participation in coastal and water quality management processes.

Statements on Public Participation	% Agreement
• public participation policies need to be been fully incorporated into science and decision making processes	90
• avenues are available for participation in related activities such as interpretation, education, research and monitoring	90
• involving the public delays the implementation of important management changes	80
• public participation process is time consuming and expensive	70
• appropriate structures and mechanisms are established to provide avenues for public participation	60
• adequate staffing and resources are provided to manage an effective public engagement program	60
• involving the public allows some interest groups to have too much influence in decisions	30
• public participation is not important because marine and coastal managers know what is best for our natural resources	10

The identification of the public for the sensor network initiative was not a straightforward task. Most respondents, from both science and management fields, reported that they had never thought about it and that identifying "the public" for their daily based activities is usually a complex process. Overall, respondents from the environmental management field tended to recognise that the public would be institutional contacts, formal organisations, government, industry, science, informal organisations and interested individuals. For instance, Natural Resource Management (NRM) bodies and GBRMPA would be the major clients for this sort of technology. Secondary clients would include groups such as CaneGrowers, fisheries groups, marine and tourism oriented business. Researchers and IT/GIS were less specific and characterised as public all people, groups or institutions who usually respond or are interested in the resource management, such as the Australian Centre for Tropical Freshwater Research (ACTFR).

Therefore, the following bodies represented at the workshops are the relevant groups and the potential public for the sensor network initiative:

- Australian Institute of Marine Science (AIMS);
- Australian Centre for Tropical Freshwater Research (ACTFR);
- Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO);
- Burdekin Dry Tropics NRM (BDTNRM);
- Conservation Volunteers Australia (CVA);
- Department of Primary Industries and Fisheries (DPI&F);

- Environmental Protection Agency (EPA);
- Great Barrier Reef Marine Park Authority (GBRMPA);
- James Cook University (JCU);
- Marine and Tropical Science Research Facility (MTSRF);
- Queensland Government Natural Resources and Water (NRW); and
- Townsville City Council (TCC).

The lack of public engagement and the absence of credibility in research initiatives and management decisions can represent a major obstacle to the adaptive implementation of innovative technologies. The next section will discuss some of the key points found in this attempt to engage with stakeholders at the early stages of the development of sensor network technology in the GBR region.

6.4 Discussion

Strategic data collection is seen to be the core issue of the environmental monitoring process, and the sensor network initiative represents a promising technology to capture data at the right spatio-temporal scales (Kininmonth *et al*., 2004; De Freitas *et al*., 2007). Nevertheless, there are considerable challenges to better understand the relationships between coastal managers and sensor network developers. Relevance, data accessibility, acceptability and context-dependence were reported as key factors in producing and disseminating real time data and information of sensor network technology in the GBR region for sensor network researchers and coastal managers (see Fig. 6.4a-b).

The need to distinguish between data and information was a core issue in the sensor network's case. Data is usually defined as 'a body of facts or figures that have been gathered systematically and from which conclusions can be drawn (e.g. survey field notes), while information is characterised as 'data that has been processed into a form that is meaningful to the recipient (e.g. statistical data that has been shaped into a pie diagram) (Ng'ang'a *et al.*, 2005). While there is still a need for raw (unprocessed) data, most coastal managers and practitioners demand access to the information processed data (Green, 2007; Szaro *et al*., 1998). Sensor network's stakeholders reported similar definitions of data and information by stating, for instance, that:

> *"data it is just lots of numbers unless some analysis is done and transform it, so data goes from being just data into information".*

Understanding the conceptual basis of 'data' and 'information' within a specific context represents the first step towards the adoption of more participatory initiatives such as the sensor network.

The relationship between the different data management domains, such as data availability (making data publicly available), data interpretability, and data ownership will foster public expectation towards management decisions. Both managers and researchers established a direct relationship between the public availability of data, rising public expectations and demands over more readily managed responses to environmental problems. The potential misinterpretation of the data provided raises complementary concerns. These were the most important factors in asking the questions of whether, where and when to make raw data publicly available. The data analysis also showed a direct relationship between data ownership with public availability of data and data interpretation by different users. To better address those points within a science-management focus, it is useful to divide the discussion into three themes: the readiness of management to adopt new technologies; the capacity of the technology to adapt to management needs, and the provision of information versus improvement of management decisions.

Are managers ready to adopt emergent technologies like the sensor network?

Environmental managers from the GBR region are eager for information that can better support their management decisions. The question is, do managers need new information or do they need better ways to integrate and communicate existing information? There is still lack of confidence on the provision of data that fits specific management and research questions, such as the relationship between delivery of dissolved inorganic nutrients from the catchment and the concentration of dissolved organic nitrogen in the long-term in the GBR lagoon. Additionally, parameters to be measured by the sensor network have to be better linked to a specific management problem, so a more purposive collection of data can be designed.

Managers' and policy-makers' lack of confidence with incorporating scientific based data has also been recently reported by other studies in the water management field (e.g. Borownski & Hare, 2007; Brugnach *et al*., 2007; Slob *et al*., 2007). Hanson (2007) underlined the fact that science is also about connecting people and acquiring trust and collaboration, sharing data and expertise, and achieving common outcomes. The best solution to address this lack of confidence has been the adoption of a more participatory approach in which different stakeholders are engaged in the early stages of the design and implementation processes (Hart and Martinez, 2006; Slob *et al*., 2007). In Europe, for instance, Brugnach *et al*. (2007) attributed the lack of policy makers' confidence in incorporating water modeling information into policy formulation to a poor communication process in which the policy makers had a lack of understanding of the use of models in the decision-making process. Throughout the participatory process, policy makers started to accept the uncertainty embedded in the prediction models, but they were still not satisfied with models changing through time, which could affect the outcomes of decisions based on assumptions derived from different models.

The main advantage of the adaptive management approach over conventional methods (e.g., the decision approach, the best-current-data approach, the monitor-and-modify approach), is its iterative and flexible process in which decisions are made by learning from actions in the face of uncertainty and complex situations, rather than deciding on actions upfront even when information and understanding are limited (Johnson, 1999). For example, in the U.S., the management of the Everglades wetland and the Colorado River systems shifted from a traditional (equilibrium-based) to an adaptive management approach (Johnson, 1999). In these cases, the previous traditional decision-making approaches failed because they attempted to maintain an optimal state of the resource under management rather than develop an optimal management capacity. The management of such systems with an equilibrium-based approach reduced the ability of the system to respond to stresses and reduced the flexibility of the management agencies to respond to changes in the system because they were unsure of how to respond to unpredictable changes. The shift towards to an adaptive approach to the management of the Everglades and Colorado River systems has enhanced the communication and cooperation among the interested parties to discuss management problems, data availability and the assessment of data gaps and uncertainties involved in complex management decisions.

By adopting an adaptive and participatory approach in the GBR region, the hope is that managers will be more prepared to use real time data to respond to complex and uncertain situations because they are learning and exchanging information from the initial stages of the development and implementation of the sensor network technology. To achieve this, technology developers and data users addressed current uncertainties about the benefits of real time information over the costs of data collection in large and complex systems such as the Great Barrier Reef. In its first phase, the adoption of an adaptive management approach involved 14 interested parties, identified tangible research and management questions, variables, requirements and limitations, for a meaningful implementation of the sensor network technology. It also addressed the most appropriate temporal and spatial scales, and a list of priority sites (from catchment to reef) for the deployment of the sensor network.

The complexity of policy management scales and the top-down decision-making processes represent additional challenges in linking science, policy and decision-making processes (Jacobs *et al.* 2005; Brugnach *et al.*, 2007). The establishment of monitoring systems at the local and regional policy scales was reported as a major problem by both researchers and managers in the case of sensor network technology. For instance, a workshop participant reported that the establishment of water quality monitoring requirements at the regional level stated that local managers needed to monitor the water quality of rivers in the Burdekin Catchment in the dry season when, because of low flow conditions, there is a minimal amount or no water in the rivers. The spatial and institutional differences between national, regional and local policy scales are therefore a significant challenge to the implementation and use of the sensor network technology.

The adoption of a participatory process with the early engagement of both researchers and managers in predicting stakeholders' needs and providing timely and relevant information represents a promising way in which managers can benefit from the deployment of the sensor network technology.

Can emergent technologies readily adapt to management needs?

Understanding the management context in which sensor network information will be used is an important step towards the usefulness of providing real time data to fit into management priorities. Nevertheless, there are still organisational, technical, and infrastructural barriers to overcome (see Table 6.3). Organisationally, the lack of policy and legal frameworks towards data standards and sharing represents an immediate challenge to be addressed. Moreover, some managers participating at the workshops believe that the technology might be well ahead of the management needs and that shortage of data is not as problematic as the decision-making process. For instance, a sensor network researcher reported that policy development usually goes through several stages until it is accepted; during this process of valuable information gets lost.

Emergent sensor network technologies can be readily adapted to management needs if some infrastructure and data management issues are solved, such as data aggregation, workflows (automatic processing), access and security, discoverability, standards (sensorML, OML), and hardware and software interoperability. The development of standards (accessibility and use of data) has been reported as essential to provide consistency in the interfaces between data, users and systems (Hart & Martinez, 2006). Standards facilitate data sharing and increase interoperability among information systems by describing the rules, guidelines and definitions of data collection and sharing (Ferreira & Lucius, 2007; Ng'ang'a *et al.* 2005). Another important aspect of technology readiness and data sharing is custodianship (Diacono, 2007; Ng'ang'a *et al.* 2005). In the case of the sensor network initiative, workshop participants stated that the responsibility over the data collected should be with the 'people who designed the data collection processes, so in this case the custodian of the sensors' data would be the AIMS.

It was also established that the custodian should also be responsible for data acquisition, storage, maintenance, quality assurance, security, access, documentation and distribution of the real time data. However, this responsibility for data interpretation and dissemination there was not a consensus; rather it was stressed that such role would require a 'third party'. Such neutral body would be one of the "boundary organisations" defined by Guston (2001) as "organisations that have a foot in both science and policy worlds and can credibly talk to both". Nevertheless, the challenge would be to define such data integrators, this frontier involving politics and science.

Emergent sensor network technology will be more prepared to adapt to, and to be adopted by, management needs if the data sharing methods are well established. It has been reported that among the reasons why datasets should not be widely available is that 'data producers might not want their data scrutinised – if data were not collected to prescribed standards or there is a suspicion that data interpretation was incorrect' (Ng'ang'a *et al.* 2005). Both reasons were found in discussions about data sharing in the sensor network workshops. Participants reported that:

> "*data suppliers and designers don't want to hand their data to anyone else before they make some interpretation in the data because they are concerned that it might be misinterpreted and that erroneous assumptions about data quality could emerge*".

They also stated that because machines occasionally fail or are not properly calibrated, the immediate availability of real time data to the general public could lead to wrong interpretations. Another reason found for not providing raw data is that researchers tend to be "*very protective of their data and they don't like it to become immediately available before their publications are released*".

Besides, researchers and managers are quite reluctant to have different users making erroneous assumptions about data quality. In most cases managers and data collectors are in reality intimidated by the possibility of losing control and receiving extra workload issues (Diacono, 2007). Both factors have been found in the sensor network's case and they were mentioned earlier in this section.

Data sharing is a meaningful cornerstone in integrating science into the policy making process (Jacobs *et al.,* 2005). However, recent studies revealed that there are some reasons for not sharing datasets (e.g. Ng'ang'a *et al.* 2005) including: collection of data with private funds or for a very specific project; privacy and security issues associated with the data (e.g. location of military, nuclear reactor facilities), and sensitive cultural information. Many of these impediments can be overcome by the development of data sharing agreements and collaborations (Diacono, 2007). It is important to consider though that, under the Freedom of Information Act (1982), the public may request access to government documents and, unless the document is subject to a specific exemption in the Act, the government agency must provide that access (Cullen, 1997).

Therefore, it is important to include the development of well defined data management principles and guidelines in the design phase of data collection initiatives. For hardcopy data, privacy can be easily assured by allowing access only to permitted parties, whereas for digital online data several steps must be considered (Ng'ang'a *et al.* 2005): i) password protection system (restricts access to registered users); ii) link only a data description online, storing the data on a separate, inaccessible system, and iii) provision of only data products (such as maps, tables, graphs) without supplying the raw data used. Similar suggestions were identified by sensor network stakeholders during the workshops and interviews. For provision of sensor network real time data, the stakeholders stated it would be necessary to:

- design specific standards and a quality assurance plan to improve the accessibility and use of the data. These would include issues about metadata accuracy and the interoperability and harmonisation of geo-spatial data through the development of a set of principles and guidelines. Consideration of existent data management strategies. For example, the 'Australian Government Custodianship Guidelines', or regional approaches such as Queensland - Spatial Imagery Acquisition Program 2007-2011 (Department of Natural Resources and Water), Western Australia - Shared Land Information Platform (SLIP where technology allows real time streaming of information from various agencies online), and Victoria – Victorian

Geospatial Information Strategy, Department of Natural Resources and Environment);

- the development of a data interpretation and dissemination plan for the end user describing data accuracy and credibility issues, and
- the establishment of a science-management calendar containing key timelines of the decision-making (annual or seasonal) process in which real time information is mostly needed. So, information is not lost and it is available in a timely fashion for decision- making.

Does the provision of information lead to better management decisions?

Overall, researchers and managers have found it difficult to develop the types of relationships and information flows necessary for full integration of scientific knowledge into the decision-making process (Jacobs, 2002; McNie, 2007). The simple provision of improved information does not directly lead to better management decisions because managers and decision makers have usually found themselves constrained by institutional and organisational impediments, and also different values and timing. In addition, the lack of total accuracy and uncertainty in datasets and modelling data is still a critical limitation for most decision-making processes (Bruganach *et al*., 2007).

The establishment of two-way communication processes, and development of long-term relationships are considered key factors for better management decisions (Borowski and Hare, 2007; Roux *et al.,* 2006). The provision of timely and useful information certainly represents an important step towards this direction, but a participatory approach with the engagement of all interested stakeholders is required. For instance, the interaction between multidisciplinary scientists and data users was fundamental for the development of an effective and widely supported science-policy communication model for air pollution management in Europe. However, the incorporation of various stakeholders, particularly from government organisations, is usually threatened by the variable position of many policy makers who are often appointed for short-time periods and may not have the opportunity to develop long-term relationships (Jacobs *et al.*, 2005).

Therefore, to support better management decisions, the provision of real time data by sensor networks will need to promote ways of improving and maintaining robust relationships and the interest of all the relevant stakeholders. Such relationships are highly dependent on continuous communication processes in which researchers communicate effectively with nonscientists, and managers express their needs for real time data. Most of the key informants interviewed (80%) for this study believed that managers do not articulate their needs effectively, and 70% believed that researchers do not communicate scientific results effectively to a nonscientific audience. Additionally, 90% of the interviewees agreed with the statement that 'policy's main challenge is the early engagement of scientists and policymakers in the initial framing of management priorities'; and also 90% agreed that 'science's core challenge is to share scientific data in understandable terms and to respond to emergent policy needs'.

Dissemination of data and information collected by a real time sensor network is an important component of an adaptive and participatory process. Stakeholders participating in the workshops and interviews reported that a useful provision of real time information could be similar to the ReefTemp initiative[14] and it would need to:

- include visual maps and graphics with different colours representing the different variables measured (maps could have a click move pointer tool similar to the Google Earth maps),
- design contour maps representing high and low temperatures through red and green, respectively, for selected reef hotspots;
- send hazard warnings (e.g. high temperatures, oil spills) throughout, for instance, an email alert system, and
- accommodate archiving facilities within the network-based tool allowing access to past time data records and present trends.

They also thought that a useful dissemination tool for the provision of real time data would be an interactive online interface with integrated restricted and public access interfaces. The restricted access portal would have a login-password protected portal in which only researchers and managers linked to the project, and other permitted users would have access to the raw streams of real time data; and a public access composed of interpreted information presented as a data summary of trends and indicators, preferably as visual maps, graphics and reports; restricted data requests would be under authorisation.

[14] ReefTemp is a collaborative initiative between CSIRO Marine and Atmospheric Research (CMAR), the Great Barrier Reef Marine Park Authority and the Bureau of Meteorology. ReefTemp include: data acquisition, calculation of climatologies, calculation of thermal stress indices, representation of bleaching risk, data and image processing, and Google Earth application development and automation. (Further information can be found at: http:// /www.cmar.csiro.au/remotesensing/gbrmpa/ReefTemp.htm).

Although there is a challenge in collating and delivering the right data at appropriate spatial and temporal scales in a cost- and time-effective manner, there is a great potential for use of real time data from reef-based sensor arrays in policy and management decision-making (De Freitas *et al*., 2007). A linkable workflow between technology developers and data users considering a range of spatio-temporal scales is important to develop a full understanding of the adaptive provision of new geospatial data. Therefore, the implementation and adoption of sensor networks technology and real time data needs to consider and integrate four main aspects: i) relevance, ii) accessibility of findings, iii) acceptability, and iv) context integration.

6.5 Chapter Summary

The deployment of a wireless sensor network and the availability of real time data in the GBR region represents a practical context to better investigate the linkages between spatial-temporal and institutional contexts, as well as interactions between data providers (information suppliers) and data users (information clients). By demonstrating a problem-oriented approach in the GBR region, this case study contributes towards a participative process by filling the information gap between the suppliers of scientific information and user demands for the adoption of emergent technologies such as the sensor network. It addresses important elements of the proposed analytical framework by providing practical information on the social, institutional and technical aspects, processes and frames that influences collaboration with developers and potential end-users as well as the collection and responsive delivery of wireless sensor network data in the GBR region.

Sensor network technology is a growing field and holds great promise for the automated intelligent monitoring and adaptive sampling of marine and coastal systems by providing management critical information in real time. In this study, valuable information was obtained about the technical and applied aspects of deployment sensor network technology. Nevertheless, some areas still require considerable effort (e.g. biological sensing, data provision and display) in order to ensure that the technology and its resulting data are both acceptable and usable to support management actions. Key contextual aspects and recommendations are briefly described below.

The use of a qualitative approach was very useful to elucidate opportunities and pitfalls of environmental sensor networks, update information on new technologies, and strengthen relationships between science and management. Findings identified a great potential and interest from both scientists and managers for continuous and automated monitoring of water quality parameters. Researchers, managers and decision makers require answers to significantly different questions and depend on real time spatial data. As such, there is clearly a need for research to extend the linkages and develop meaningful ways of interaction between technology developers and users. Particularly, the definition of more specific purposes for providing real time data; translation and delivery of raw data into usable and understandable information requires further exploration and continuous evaluation.

The development of new information technologies such as the ESNs need to be mainly management driven, but with both science and management working in a collaborative way to set the purpose and standards for data collection and analysis. Environmental managers and decision makers would be responsible for designating the policy/management problem and to communicate their information needs to scientists. Scientists would need to better understand and fit management priorities into their research purposes. Additionally, technological and infrastructural challenges, such as destructive environments, limited radio transmission range, information security problems, and visual pollution still need to be overcome.

The collection and dissemination of real time data needs to be fitted into a well-established purpose and defined context, and the technology has to be functional at the regional scale. Data provided by geospatial technologies such as the sensor network needs to be supported by adequate mechanisms for information delivery. In this sense, workshop participants stated that such delivery mechanisms need to: i) develop dissemination information plan for the end user; ii) establish a system of easy integration of data; iii) address liability and data sharing issues; iv) scalability questions; and v) elaborate a collaborative user-friendly web platform for data diffusion.

The intended public for the sensor network and real time data at the GBR scale is mainly local and regional environmental bodies and research organisations. Further efforts are still required to enhance the communication flow between researchers, managers and technology developers across the information processing chain. In addition to communicating with stakeholders during the initial stages of the project development, it is important to continue to communicate throughout the entire process. Therefore, the establishment of more structured partnerships, such as an Informal Steering Committee Support Group, is to be recommended.

Possible future work includes studying issues on spatial data infrastructure (SDI) and collaborating on linkages with the scope of national data management initiatives such as the Integrated Marine Observing System (IMOS). Such studies would greatly reduce difficulties such as duplication, fragmentation and diffusion of collected data. Additionally, it is also necessary to develop a robust set of principles and guidelines for interpretation and dissemination of real time data.

Chapter
7

REVIEW SYNTHESIS AND DISCUSSION

Application of the Conceptual Framework for Linking Public Participation, Spatial Information and GIS in the Management Process of the Great Barrier Reef Tropical Coast

Abstract. The previous chapters have shown the different contexts, needs and constraints to public participation in the use of spatial information and GIS by key stakeholder groups (recreational fishers, coastal managers, government agencies, industry, landholders, science providers and community-based organisations) in three real management situations (water quality, rezoning GBR, and emerging geospatial technologies) and scales (catchment, coast and marine systems). The aim of this chapter is to develop a conceptual framework that integrates the main social, institutional and technological aspects that emerged from the analysis of the case studies. The framework evolved from the substantial body of literature, as well as analysis of data gathered during this research. The contributions of the study to the research field are also presented. The chapter concludes with a summary of major findings, overall limitations and recommendations for future research.

7.1 Revisiting the Research Questions

In previous chapters, the issues of participation and the use of spatial information and GIS have been explored and examined using three practical management contexts. The overall purpose of this research was to investigate and document the extent to which public participation processes and geospatial tools have been developed in practice. This chapter concludes the thesis by revisiting and addressing the research questions posed in Chapter 1. It summarises the main aspects that emerged from the analysis of the case studies providing an appropriate conceptual framework for understanding the linkages between participation, spatial information and the use of GIS in land use planning and water quality management processes.

This chapter integrates the findings of Chapters 4, 5, and 6 to develop a coupled public participation and GIS framework identifying whether the key drivers, needs and limitations of different stakeholders within the context of the GBR tropical coast are supportive of PPGIS initiatives. It seeks to understand and connect the results of the three case studies addressing the needs and challenges for linking public participation and spatial information and technology in the management of natural resources. The development of a conceptual framework based on practical management situations provides a cohesive and systematic way of understanding the socio-technological and institutional contextual factors that influence people’s participation and shape the use of spatial information and GIS-related technology. As previously stated in Chapter 2, the framework does not attempt to technically evaluate the merits of various geospatial software and their products. Rather it serves as a theory-building exercise and offers suggestions for future directions.

The chapter concludes with a summary of the major research findings and conclusions that arise from this research. It also presents the implications, recommendations, and potential extensions that flow from this research. Conclusions are made with reference to socio-institutional and technical factors that influence the extent to which public participation processes and geospatial tools have been developed in practice for managing natural resources in the GBR tropical coast.

Q1. How is ‘public’ and ‘participation’ manifested in the context of the Queensland tropical coast and among different stakeholder groups for the three case studies?

Results showed that the ‘public’ in the situations investigated is manifested by those directly involved, highly interested and remarkably, knowledgeable in the subject under discussion. Regardless of the differences inherent to each case study, most of the ‘public’ was composed of individuals and interested groups who want to express their opinions and have their concerns incorporated into the decision making process. Within the three case studies analysed, the public was composed of key representatives of diverse sectors involved in land and water management activities including sugar cane farming, grazing, natural resource and water quality managers, government and non-government organisations, researchers and technology experts. Nevertheless, most of the participants, including representatives of management agencies, from the three case studies found it difficult to identify the ‘public’ for their daily based activities and, in many cases, they had never thought about it. Difficulties in identifying who constitutes the relevant public are not particular to this research and have been reported elsewhere (e.g. Barnes *et al.*, 2003; Schlossberg & Shuford, 2005).

Similarl to the usage of spatial information and GIS technology, the ‘public’ within the scope of the case studies has been manifested in a commodity and project-by-project fragmented basis, thus not fully incorporated in all phases (from design to implementation) of the decision making process. As the findings of the case studies showed, this has been reflected in the way that the relevant public identify their role in the planning process (Chapter 4), perceive whether or not their concerns have been adequately incorporated in the decision making process (Chapter 5), and how they expect to be continuously engaged from design to implementation stages of the project development (Chapter 6). Findings of this research provided valuable contextual information that support understanding of how different the public is represented and linked to certain forms of participation in three practical decision making situations.

In terms of ‘participation’, findings indicate that an effective engagement program in NRM should be one that results in the best outcome for the natural resource but that also is fair and representative for all affected groups. Meaningful participation should be a process easily understood by everyone allowing people to express their views and provide a genuine opportunity to incorporate people’s concerns into decisions. It should also integrate public participation policies into science and decision making processes. This supports findings, such as those of McCall (2005), that participation within a participatory GIS context is represented by legitimacy, equity, accountability and respect. This does not mean, however, that the highest levels of participation (mainly represented by empowerment or control) have to be the ultimate objective of a meaningful participation process. Rather, participation needs to be appropriate to the tasks, competencies and the specific relationships between the stakeholders involved in the context (McCall, 2003). The appropriateness of different forms of participation is highly dependent on the contextual factors in which the decision-making process takes place (Silver & Campbell, 2005). Low, peripheral or non-participation are also valid and legitimate choices in some situations (Hayward *et al*., 2004).

Nevertheless, confusion about intensities and purposes of participation has lead to misconception that 'participation' means different things to different people in different settings (Hayward *et al*., 2004; McCall, 2003). In reality, McCall (2003; 2004) suggests that participation in participatory GIS, as in other processes, has to be examined not just in terms of the procedures and activities by which it is operationalised, but also in terms of intensities of participation (from the lowest to the highest participatory: information sharing, consultation, decision making, initiating actions) and the intended functions (facilitation, mediation, and empowerment) in participatory spatial planning. It is, therefore, the mutual interaction between intensity and function of participation that reflects the underlying purposes or intentions of management agencies in 'pushing' participatory spatial planning and/or promoting participatory GIS in the decision making process (McCall, 2003). At one extreme is 'facilitation', when participation is promoted to introduce outside programmes, whereas the other extreme is 'empowerment', where participation is intended to prioritize local decision-making, reinforce responsibilities and give voice to local people (Elwood, 2008; McCall & Minang, 2005). Coming in between is 'mediation' or 'collaboration', where the intention is for the participatory approach to trade-off the interests and priorities of outside projects and local people (McCall & Minang, 2005).

Therefore, investigation of practical decision making situations is essential to better understand how participation is perceived and manifested among different stakeholder groups for the three case studies. In Chapter 4 of this research, for instance, the majority of the participants identified consultation as a satisfactory form of participation. However, results showed a significant need for improved communication and feedback between natural resource managers and users. For most participants, mainly landholders, an effective engagement and participation process greatly relies on the interaction with the management officer, established networks and personal relationships, and provision of relevant information at the property-scale. In Chapter 5, recreational fishers reported a high level of dissatisfaction with the consultation process used to engage them in the rezoning of the Great Barrier Reef. They do not make claims for a higher level of participation, but they do believe that the formal two-phased consultation process providing map-questionnaires and collating public written comments was not sufficient to truly incorporate their concerns and significantly minimise adverse impacts on recreational fishers. In Chapter 6, reef managers, water quality researchers and sensor experts stated that involvement and long-term collaboration at early stages of technology development is critical for an effective participation of potential end-users.

Overall, results highlight the importance of maintaining a strong and productive relationship between resource managers and resource users, and the importance of ensuring meaningful engagement in the management process. Commonly, participants of the three case studies believe that government and NRM agencies should incorporate their concerns in management-related processes. Participation in such issues is mainly driven by participants' interest in being informed, their personal attachment with natural resources and their desire to truly influence decisions that are reflected in substantial actions on the ground. Most importantly, participation also means trust in the management agency and reliance on an open and transparent process with no pre-determined outcomes. Distrust and perceptions of a top-down agency driven process with pre-defined results was reported as a major constraint for meaningful participation by stakeholders in Chapters 4 and 5. Landholders (Chapter 4) and recreational fishers (Chapter 5) reported a high degree of scepticism about the 'true' agenda of government-related meetings. The issue of trust and hidden agendas was not identified as a major factor influencing participation within the context of the adoption of spatial sensor technology by coastal managers (Chapter 6). Instead, an efficient communication process where managers articulate their needs effectively and researchers communicate scientific results effectively to a non-scientific audience was the key aspect of a meaningful participation process.

Finally, participation also means a balanced (mixed) and diverse representation of stakeholders and interests. Imbalance and over-representation of industry groups and local government authorities was found to be the major cause of failure for achieving or maintaining an adequate participation of community sector interests and organisations in NRM (McCall 2005; Larson & Lach, 2008 Whelan & Oliver; 2005). Concerns about representative participation were also found to be an important issue within the context of the case studies investigated in this thesis. In the development of the Burdekin Water Quality Improvement Plan presented in Chapter 4, for instance, participants highlighted the need to optimise representation while minimising overlap of interests and the number of people represented in the steering committees. Different committees and working groups have been implemented for different aspects (e.g. agricultural pressures, environmental values) of water quality management plans. However, in many cases, these committees are composed of similar members. An evenly balanced representation of the stakeholder groups and interests, as well as better integration at the local and regional levels are, therefore, essential components of a meaningful participation process in the context of NRM of Queensland tropical coast.

Q2. Are the ways that spatial information and GIS technology presented to and used by key stakeholder groups to support informed decisions in natural resource management supportive of PPGIS initiatives?

The current spatial information and GIS technology strategies and mechanisms used within the context of the case studies investigated are not full supportive of PPGIS initiatives, at least not to the complete extent of the PPGIS definition, and not within the context and timeframe analysed in this research. Nonetheless, this research recognises that there is potential for improvement if stakeholders' interests and needs are better addressed by the available spatial information and GIS tools. Some specific suggestions have been made through the development of this thesis, particularly in the case study chapters 4, 5 and 6. Some scenarios of how PPGIS initiatives would look based on the existing mechanisms and participation strategies are outlined in Figure 7.1. The generic framework proposes four possible extreme scenarios representing the current status of the intersection between the level of public participation with the level of usage of spatial information and GIS initiatives based on the existing mechanisms and participation strategies.

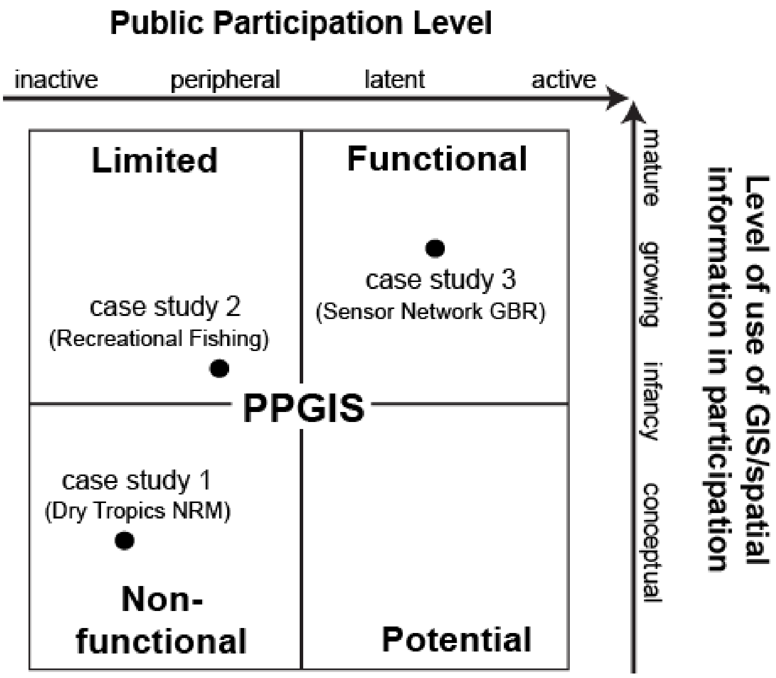

Figure 7.1. A generic PPGIS framework integrating levels of public participation and use of spatial information and GIS in public participation.

The scenarios in Figure 7.1 indicate that, despite constraints, the intersection between public participation with spatial data and GIS technology usage can potentially play an important role in NRM and decision-making processes if contextual factors are better considered. Within the scope of the case studies investigated by this research three of the proposed scenarios were found possible: (1) non-functional, represented by case study 1 – Chapter 4, (2) limited, characterised by case study 2 – Chapter 5, and (3) functional, manifested by case study 3 – Chapter 6. The distinct possibilities in PPGIS scenarios found in this research might be broadly explained by the fact that, in the first (Chapter 4) and second (Chapter 5) case studies, the decision making process has been mainly driven by the management agencies to fulfill government requirements for public participation. In this case, both participation and spatial information/GIS usage have not been initially designed to directly address the interests and needs of a wider range of different users. These case studies characterize situations of a more rudimentary and not fully supportive form of PPGIS initiatives in their present stage. In the third case study (Chapter 6), however, the intersection of public interests with geospatial information was aimed from the beginning of the process. The purposive collection and delivery of sensor network data has been directly designed to address the specific needs of potential users characterizing a functional PPGIS initiative. These scenarios are explained in detail in light of the contextual factors while revisiting the fourth research question (Q4).

The fourth scenario, **'potential'**, represents a hypothetical situation not characteristic of the case studies analysed by this research (lower right quadrant of Figure 7.1). In this situation, active participation, although still in a dormant stage, is promoted by an open organisational context in which the management of natural resources occurs in direct collaboration with resource users. The use of GIS and spatial information is almost non-existent and mainly inactive limited by people's lack of skills to manipulate and interpret spatial data, limited knowledge about available sources, and restricted funding to acquire spatial data at the relevant scale. This might be exemplified, for instance, by a non-government volunteer organisation in which volunteers are usually highly motivated and interested in the activities in which they are engaged. Although this research did not directly involve such organisations, they were represented as one of the key stakeholder groups within the scope of Chapter 4. Greening Australia and Conservation Volunteers Australia, for instance, were found to be critical for bridging the communication gap between NRM bodies and the community. Those organisations also demonstrated a high level of interest in the use of GIS and spatial data to support their volunteer activities and to better communicate their actions. Consequently, their potential for growth towards a truly PPGIS approach would be greatly facilitated, for example, through collaboration with research institutions and private spatial data providers.

Overall, participants in this research recognised the increasing role for public participation and the growing use of geospatial data and related technology for informing and consulting about NRM and decision-making processes. Nonetheless the available spatial information and GIS technology have not been fully addressed by the available spatial information and GIS tools. Uncertainty about data sources, inappropriateness of the information provided, lack of technical skills and spatial expertise, and inadequate infrastructure were common factors found in the three case studies investigated in this research.

If PPGIS constitutes an array of topics and initiatives raised by the intersection of public interests and GIS technology to provide equitable access to spatial data and GIS while facilitating participation (Elwood, 2008; Ghose 2007; Rambaldi, 2006), then the provision of spatial data and use of geographic tools needs to be tailored to the immediate needs of the stakeholders. Not surprisingly, this research has shown that while government, research institutions and NRM agencies dominate access and dissemination, the representation of spatial issues and use of GIS technology by other stakeholder groups is still restricted.

To be more supportive of PPGIS initiatives, existing participation mechanisms and the main sources of spatial information need to shift from a supply-demand and specific commodity driven approach to a more responsive, integrative and participatory approach. Results of this study found that, despite technological advances, people still rely more on word-of-mouth, face-to-face communication, trustful and stable relationships, and effective on-ground and best practice examples as main sources of information (including spatial data) and communication strategies. Therefore, to better support PPGIS initatives, substantial and long-term investments in extension personnel and local expertise and in building and strengthening relationships between resource managers and users are necessary. Currently, much effort is focused on increasing the quantity of information provided and acquired, whereas the quality of the process has been left behind. For instance, Chapter 5 showed that despite the extensive spatial consultation process, which received over 31 500 map-based written submissions, recreational fishers were highly dissatisfied with the consultation process used to engage them in the rezoning plan of the Great Barrier Reef Marine Park. Lack of trust in the management agency, disorganised public meetings, provision of misleading information, and perceptions of pre-determined decisions were common complaints in this case. Certainly, this also has implications for the use of spatial information and GIS in facilitating participation. Recreational fishers found that the spatial information collected during the rezoning process was misleading and was used to support the management agency in the selection of the green zones instead of avoiding overlap with fishing areas.

Second, to be more supportive of PPGIS initiatives, geospatial data and related technology need to be more easily accessible and allow more purposive applications. There is no doubt that online tools such as Google Earth are definitely "*changing the way we interact with spatial data*" (Butler, 2006: 446) by democratising and increasing awareness of GIS techniques. However, within the scope of the case studies investigated in this research, the use of online virtual globe tools by grassroots groups such as landholders and fishers is still constrained by lack of knowledge or access and inappropriateness of the information provided. As stated by farmers in Chapter 4:

> *"We have used Google Earth images sometimes in community events, but it doesn't have enough detail to show local places". …… "So, tools such as Google Earth are used just for curiosity, but they are not useful".*

The current strategies for spatial data acquisition, access and dissemination are mainly driven by government and research institutions. Consequently, most of the immediate public interests do not overlap with the GIS technology and the spatial data provided. Three major issues were found to be inhibiting a PPGIS approach in the studied contexts. Firstly, most of the available information is scattered across different institutions, and there is not a central repository database in which users are able to search and easily request the information they need. Government and non-government organisations started to provide mapping data and satellite imagery as a way to promote sustainable NRM. For instance, collaboration between Geoscience Australia and the NQ Dry Tropics NRM launched in 2002 integrate a strategic planning process to acquire and support the use of SPOT 5 satellite imagery. However, reliable and accurate data at the relevant scale is still costly, whereas data request processes are too bureaucratic and not timely. Lack of technical support to interpret and use the acquired spatial data is also a constraint. Secondly, intellectual property rights privacy and security issues associated with the data has decreased users' motivation and willingness to interact with spatial information. Thirdly, trust in the data provided was**,** on many occasions, associated with trust in the management agency responsible for data availability and use. Scepticism about the 'true' agenda of government and the NRM agency; and dissatisfaction with previous experiences reflected in mistrust about the purpose for which spatial information was used in communication and consultation processes.

Most of the problems and deficiencies attributed to PPGIS and participatory mapping processes are, in fact, the result of complex relationships between geo-information (GI), GI management and participatory spatial planning applications (e.g. Akingbade *et al*., 2009; Elwood, 2008; McCall 2004; McCall & Minang, 2005; van Loenen, 2009). Lack of financial resources by institutions (McCall, 2003), inadequate spatial database infrastructure and poor data sharing arrangements (Akingbade *et al*., 2009), and inconsistent interaction between users and suppliers (van Loenen, 2009) are determining factors in development of PPGIS. Although it is difficult to establish a direct cause-effect relationship between common wider problems of GI management and participatory GIS approaches in general, some studies have attempted to address the issue. For example, using participatory GIS (PGIS) and mapping in community-based forest management in Cameroon, McCall (2005) found that access, use and storage of the geographic information influenced the efficiency of participatory mapping and PGIS interventions in their contributions to good governance. This study explores the often-made assumption that PGIS have the capacity to simultaneously meet the content needs, answer the questions asked of the geo-information, and address and satisfy the local stakeholders' underlying interests. Therefore, articulating PGIS at the local level would be more effective than relying on conventional mapping and GIS, and thus, that PGIS would be a tool for better governance and empowerment (McCall, 2003). In the Cameroon case, McCall and Minang (2005) found that only the location and descriptive uses of GIS were considered in the process. While the hard copies of maps were stored with local communities, and therefore accessible to most members, access to digital geo-information was exclusively reserved to the consultant and the NGO that facilitated the process. The study demonstrates that, although such deficiency can be explained by the lack of basic GIS technology in the community, the issue was not addressed at any point in the development of the PGIS.

To enhance support for PPGIS initiatives, users' interests need to be intersected by GIS technology and the spatial data provided. In Chapter 4, for instance, existing mechanisms of spatial data delivery focus on provision of Spot satellite imagery requested, GIS training workshops, and information sessions about the available data. This could be improved by applying a more practical strategy in which a landholder, or a group of landholders, with the support of management officers, uses GIS and spatial data to produce on-ground results to support farming planning. Additionally, the following strategies represent some of the key components that need to be addressed if a PPGIS initiative is to be supported within the studied contexts:

(i) trust between government and resource management agencies with resource users needs to be strengthened urgently. Trust between stakeholder groups and management agencies could be improved by engaging resource users at early stages of the design of the processes to address the management problem. A two-way and open communication process should strengthen the quality of relationships by encouraging resource managers to clearly articulate their intentions and determine tangible outcomes, and user groups to identify their needs as well as which role they want (to play) in the management and planning processes,

(ii) parameters to be measured by geospatial technologies, such as the sensor networks, have to be better linked to a specific management problem, so a more purposive collection and use of data can be designed. Instead of being designed with the objective of the overall improvement of water quality, such technologies should be able to collect variables which allow addressing more specific issues such as the relationships between suspended sediments (rivers) and turbidity in reef systems,

(iii) investment in collaborative joint initiatives and in the use of existing structures and established community-based networks may possibly strengthen efforts, within and across interested stakeholder partners, facilitating the management, storage, access and acquisition of spatial data and geographic information technology. Costs and benefits of a central repository database and long-term technical support, for instance, could be shared between key resource user groups at the catchment scale, and

(iv) effective participation and the meaningful use of GIS and spatial information needs to be adopted as a means and a continuous process, instead of an end goal or a tool to fulfill legal requirements. Public engagement plans, data collection and dissemination protocols need to be embraced by NRM agencies as a permanent process and not on a project demand approach. These types of project driven initiatives are usually constrained by specific funding schemes and tight top-down timelines and they are not supportive of PPGIS initiatives.

Lessons learned from this research provide a practical understanding of how spatial information and GIS technology have been presented to and used by key stakeholder groups to support informed decisions in the management of natural resources in the tropical coast of the Great Barrier Reef. As stated by McCall (McCall, 2003: 570), *"GIS, or P-GIS, is not a magic bullet for improved PSP, but it is by no means only a technical fix. There are real needs and opportunities for progressive developments in P-GIS and mapping."* By investigating practical needs, opportunities and limitations of participation and use of spatial information and GIS, this research has also contributed to address some of the wider issues related to geo-information and participatory process.

Q3. To what extent does the use of spatial information and GIS strengthen traditional means of communication, participation and cooperation in the management of coastal resources?

Spatial information and GIS technology have been used mainly for consulting and informing stakeholders about land-use planning and water management activities. Its support of traditional means of communication and participation is currently limited and in most cases spatial data and GIS are peripheral to users' immediate needs. There is a consensus that spatial data and geographic information tools can create new opportunities for participation and increase people's awareness of NRM processes. Results show that the use of spatial information and related technologies is growing, as well as the potential for facilitating access to information and supporting communication in land and water management processes. Map-questionnaires to collate public comments, GIS training workshops, provision of satellite imagery, and development of online atlases represent some of the mechanisms by which spatial information and GIS add value to the flow of information and support communication and interaction between stakeholders.

Nevertheless, the inconsistent implementation of strategies and mechanisms has restricted the use and relevance of spatial data and geographic information technology to meaningfully support the participation of grassroots stakeholder groups and, consequently, promote PPGIS initiatives. These findings are consistent with those reported by Anderson *et al.* (2009) who investigated the potential of a PPGIS collaborative approach in facilitating data acquisition, assimilation, and visualization of meaningful maps needed to support community-based forest decision making in Nova Scotia (Canada). Despite the potential advantages of facilitating understanding of community priorities in planning and representation of diverse community perspectives**,** they found that issues of data acquisition, use and sharing policies substantially limited the changes of implementing practical PPGIS applications.

The diversity of requirements and usage levels found in the three case studies provided practical evidence on the multiple roles possible for a participatory use of spatial information and GIS tools. Landholders, for instance, believe that GIS-based data and satellite imagery are really useful ways to communicate about NRM issues. They use mapping data and spatial tools to support crop production planning and other land-based management activities such as location of weeds and soil mapping contours. However, uncertainty about data sources, unavailability of data at the property scale, and lack of expert support are limiting the wider adoption of spatial information and GIS. For recreational fishers, the current available data is not adequate to their immediate needs. They mainly use conventional mapping (e.g. paper maps, plotter), Google maps and GIS to plan fishing trips and localise fishing spots. Other data such as aerial photos or internet interactive maps are either not available at a sufficiently fine scale or do not provide relevant data such as bottom types or depths. In the case of potential end-users of wireless sensor data, online visual maps, graphics, and contour maps of key parameters (see Table 6.5 and Figure 6.5) were selected mechanisms for a timely dissemination and adequate use of real-time data.

Currently, the extent to which the use of spatial information and GIS is strengthening traditional means of communication is limited, but there is potential for improvement. Natural resource management, government and research organisations still represent the majority of providers and users of spatial data and geographic information tools. In this context, the availability and use of spatial information and GIS products by grassroots groups, such as landholders and fishers, are subject to a supply versus consumption market model in which government and private institutions provide whatever is feasible and relevant for their own uses, whereas the public have to choose from the available products. In many cases, however, the products supplied do not attend to users' demands. In such situations, either users decide to select the product that most closely fits their needs, or they might simply prefer not to use it. This model is not participatory and will only provide partial support to traditional means of communication and participation. For instance, results of Chapter 4 revealed that vegetation mapping data currently provided by government institutions to support farm planning does not match landholders on ground reality. Vegetation data is located inaccurately or it represents an incorrect type of vegetation.

Further and meaningful adoption spatial information and GIS will depend on provision of timely and relevant information, better integration and long-term capacity building and support, instead of a fragmented and 'commodity specific' approach. The early engagement of potential end-users in data collection and technology design, as shown in Chapter 6, represents a promising way for spatial information and GIS to benefit and strengthen traditional means of communication, participation and cooperation in the management of coastal resources. The establishment of stable and neutral bodies that translate and provide relevant spatial data and technical support in a timely and cost effective way might improve the use of spatial information and GIS in the studied region. As suggested in Chapter 4, the integration of GIS collaborative joint initiatives and the use of existing structure and established community-based networks can potentially strengthen efforts, within and across interested stakeholder partners, and facilitate the management, access and acquisition of spatial imagery and GIS.

Q4. What are the contextual (social, institutional and technical) aspects that influence public participation and shape the use of spatial information and geographical information technology, and to what extent do they support PPGIS initiatives in the context of the case studies?

The importance of contextual factors as determinants in influencing public participation, shaping the use of spatial data and technology, as well as enhancing and limiting PPGIS initiatives have been discussed throughout this thesis. Here, the key social, institutional and technical aspects that emerged from the analysis of the three case studies are presented in light of the proposed analytical framework.

The detailed framework builds on the theoretical foundation presented in Chapter 2 (Fig. 2.4) while expanding the previous generic framework of possible PPGIS scenarios (Fig. 7.1) by integrating and summarising the social and technological frames across the case studies. This synthesis provides a coherent picture that integrates the findings of the thesis based on a realistic understanding of the users and contextual factors that shape the issues surrounding participation and the role of spatial information and GIS (Figs. 7.2, 7.3 and 7.4).

Case study 1 (Chapter 4)

Constructs

This case study represents a **'non-functional' PPGIS scenario** (lower left quadrant of Figure 7.1) in which an **inactive level of participation** (stakeholders are mainly informed about management actions and consultation when it occurs is realized by third parties with minimum involvement by the management agency) and **conceptual use of spatial information and GIS technology** (people are just talking at this point but the implementation of GIS software and meaningful use of spatial information is vestigial at this point) were found. In this context, public participation is constituted as informing and consulting with relevant stakeholder groups (mainly composed of graziers, farmers, non-government representatives, managers and researchers) as part of the water quality management plan (Fig. 7.2). Stakeholders' input is sought to identify environmental values and develop water quality targets to improve water quality and decrease land-based pollutant discharges into coastal systems. The use of spatial data and GIS technology is restricted to inform and collect stakeholder's input on water quality related issues. A more interactive participation process and purposive use of geospatial data and technology has been greatly influenced by three major interrelated contextual factors.

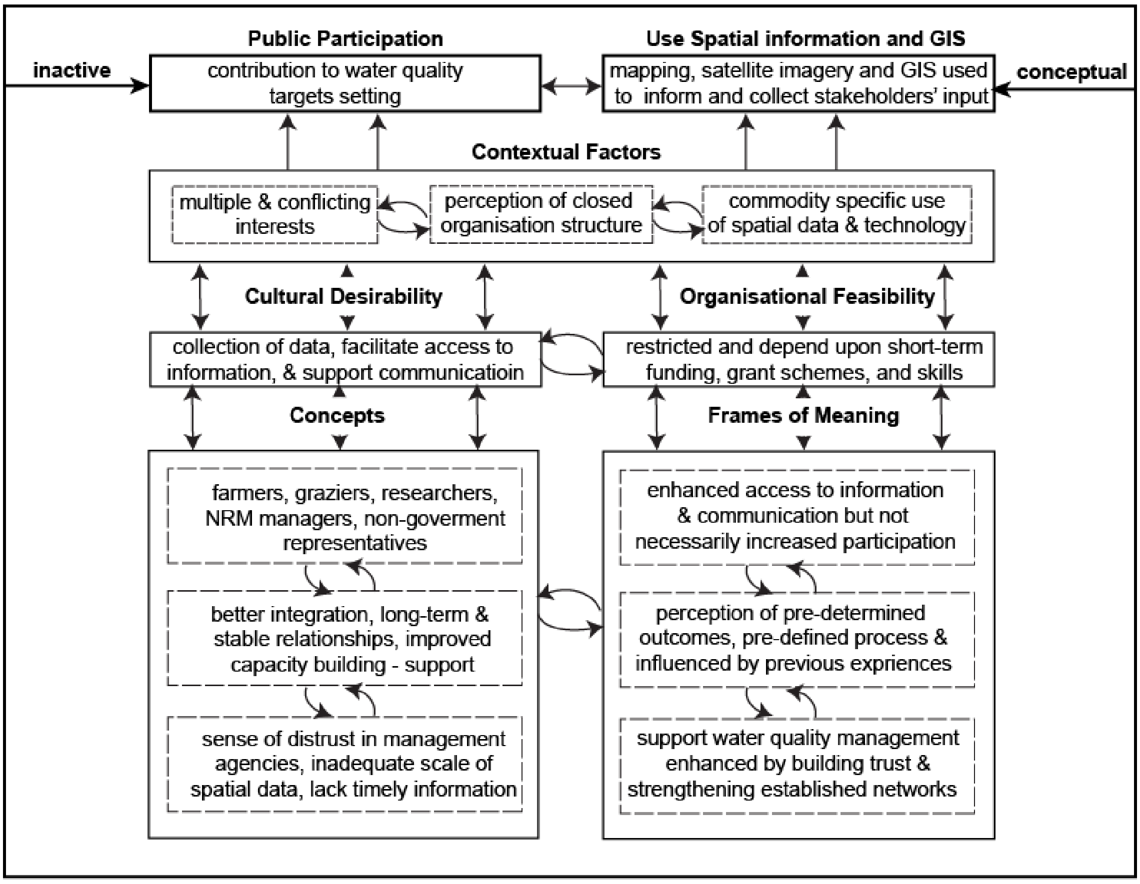

Figure 7.2. Detailed conceptual framework of contextual factors that shape participation and the role of spatial information and GIS in community engagement and management processes in water quality in the Dry Tropics NRM region (case study 1).

Contextual Factors

Firstly, multiplicity of institutions with overlapping policies and roles has fostered stakeholders' perceptions of lack of transparency, confusion and uncertainty about existing institutional arrangements and purpose of management plans. In addition, participation has been promoted by the establishment of disconnected and unrepresentative committees. This has resulted in frustration and decreased interest in participation. Secondly, NRM bodies are dependent on government-related funding and timelines which has associated them as part of the government and as closed organisations in which stakeholders' participation is either low or peripheral and limited to information provision and consultation processes. Thirdly, unconsolidated strategies for collection and management of spatial data and related technologies have resulted in a commodity approach and fragmented use of geospatial information in which a specific sector (e.g. grazing, sugar, fisheries) has its own arena of support extension and GIS applications.

Cultural Desirability and Organisational Feasibility

Therefore, although considered desirable to better support communication, facilitate access to information, and collection of relevant data, stakeholders' participation and usage of spatial information and GIS have been limited for a couple of reasons. For instance, findings of this case study demonstrated that effective engagement and participation by stakeholders greatly relies on the managing officer, established networks and personal relationships, as well as provision of spatial information at the property-scale. Nevertheless, lack of skills, tight timelines for government funding schemes, and turnover of NRM and extension personnel, were identified as main constraints for a participatory process and the use of geo-information technology.

Concepts and Frames of Meaning

Better integration between the relevant social groups with strong social networks, long-term and stable relationships and continuous capacity building were found necessary to sustain the divergent interpretations and perceptions of farmers, graziers and other relevant groups to ensure information flow and to connect people in land management practices and water quality issues in the Burdekin Dry Tropics region. Perceived sense of distrust in the management agency and its 'real' intentions while conducting a consultation process has also been reflected in the way landholders have constructed the utility of spatial information and technology as tools for supporting participation in the decision making process. In most cases, the lack of trust with mapping and spatial data provided by government organisations is instigated by provision of inaccurate location and classification of vegetation, uncertainty towards the motivations of the government in interpreting and presenting the data, and specific issues about complexity, ambiguity, validity and spatial scale.

Therefore, even though enhanced access to information and communication tools is provided, it does not necessarily increase landholder's participation. Frames associated with perceptions of pre-determined outcomes and assumptions based on previous experiences have shaped stakeholder' meanings and influenced their context resulting in lack of motivation to participate. For instance, in this case study, previous provision of inadequate information (e.g. "*We need to understand common jargon terms used such as inorganic nitrogen and its associated value"),* frustrated expectations (e.g. "*We have done these things many times before, but things do not seem to change, government does what they want to do"),* beliefs of a pre-defined process (e.g *They [the government] are doing this only to be fine with legislative requirements and political agendas*") enhanced stakeholder understanding that building trust and strengthen social networks need to be addressed if an improved support for water quality in land-based management is to be achieved.

A non-functional PPGIS scenario could be improved if some missing linkages are established. For instance, by fostering GIS community-based collaborative joint initiatives in which interested stakeholder groups shared the costs and benefits of expert support in the acquisition, management and dissemination of spatial information and GIS technology. In addition, the development of a comprehensive and collaborative engagement protocol during the project's scope phase would provide natural resource management agencies and stakeholders timely opportunities and incentives for long-term participation.

Case study 2 (Chapter 5)

Constructs

The second scenario (upper left quadrant of Figure 7.1) represents a PPGIS approach which is **'limited'** by a **peripheral level of participation** in which users are only engaged at the implementation phase of the decision process and they usually assume their concerns are not incorporated in the decisions taken. In this scenario, the **use of spatial information and GIS** is in the **infancy stage** restricted to collection and provision of information from management agencies to resource users, although its need as a decision support tool is growing (Fig. 7.3). The intersection between public interests about implications of management changes in the rezoning of the marine protected areas and the use of GIS technology and spatial information in the rezoning process is driven by three major interrelated contextual factors.

Contextual Factors

Despite claims of the management agency that an extensive public education and consultation process provided opportunities for engagement by commenting on the draft zoning plans, recreational fishers felt themselves not realistically engaged in the rezoning management process. Their late engagement in the implementation phase and insufficient time allowed for the consultation processes of the rezoning of the Great Barrier Reef Marine Park has resulted in perceptions of marginal and symbolic participation in which their concerns had no effect in influencing the final outcome. Similar to stakeholder groups in Chapter 4, fishers attribute their limited level of participation to a closed organisation structure driven by top-down governmental interests and outcomes politically established previous to the consultation process. This has lead to tension between fishers and government, low compliance with regulations, and policies that do not truly reflect the effects of spatial closures on fishers' access to marine resources and displacement of fishing activities.

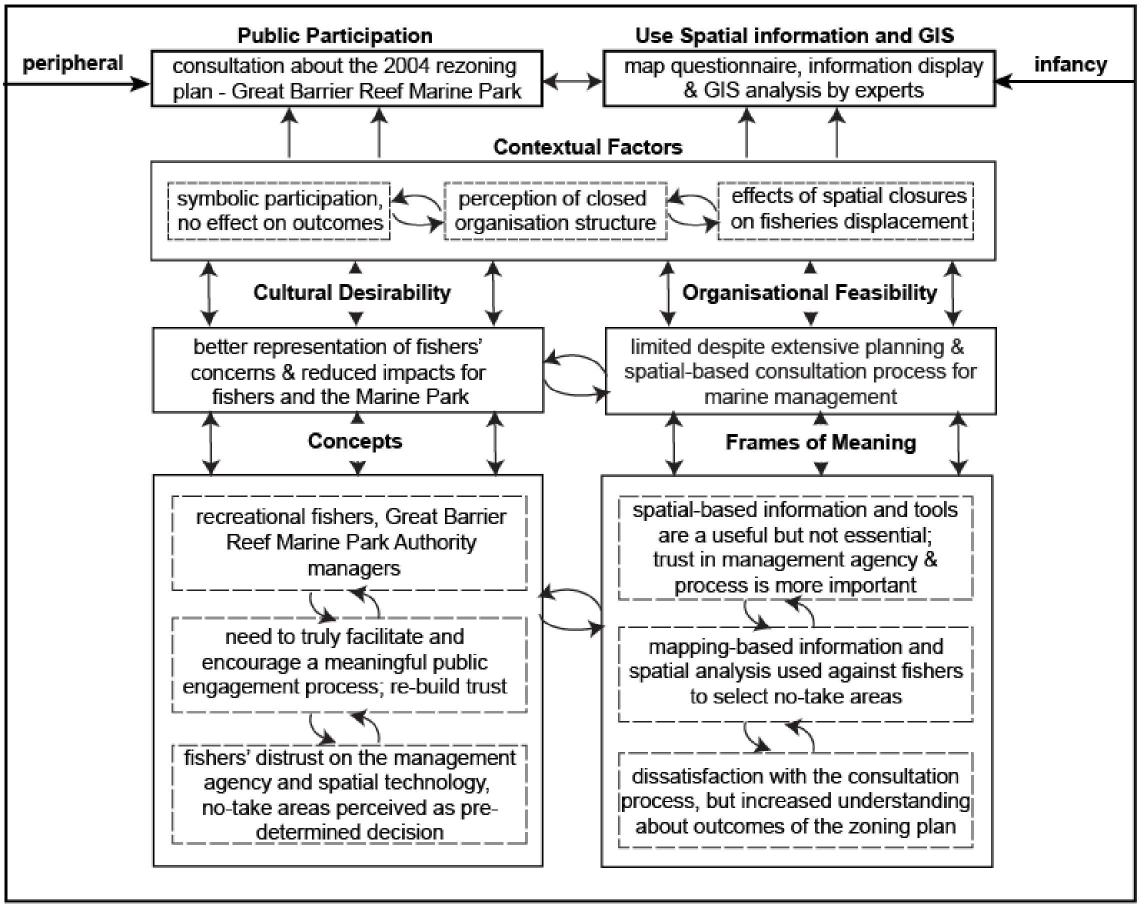

Figure 7.3. Detailed conceptual framework of contextual factors that shape recreational fishers' participation and the role of spatial information and GIS in the rezoning process of the Great Barrier Reef (case study 2).

Cultural Desirability and Organisational Feasibility

Finding meaningful ways to engage recreational fishers and marine resource managers and promote long-term involvement of resource users has been culturally and socially supported for an improved management of fisheries and sustainable use of the marine resources in the Great Barrier Reef Marine Park.. The need for engaging those resource users affected by the design and implementation of the 2004 rezoning plan has been incorporated in a two-phased community consultation process supported by the use of zoned map-questionnaires and GIS tools to collect and inform key stakeholder groups in the GBR. Clearly, both public participation and the support of geographic information techniques were used to address the critical problem of increasing the amount of no-take areas to protect the biodiversity of the GBR whilst minimising adverse impacts on resource users. Nevertheless, the consultation process used during the rezoning process has failed to fully support socially aimed expectations of recreational fishers and most fishers experienced at least some negative impacts (e.g. restricted access to fishing grounds, increased crowding in areas that remain open) from the rezoning changes. In addition, despite the extensive spatial consultation and analysis, a more participatory process and use of GIS and map-based tools has been limited by organisational related factors such as lack of knowledge or access, inappropriateness of the information provided, inadequate scale and uncertainty related to the purpose to which spatial information has been collected.

Concepts and Frames of Meaning

Different interpretations of a meaningful public engagement process and consultation techniques (zoning mapping and GIS analysis) was an important facet shared between the two socially relevant groups of this case study. Whereas recreational fishers believe that the public participation process should allow their concerns to be incorporated into decisions and provide a genuine opportunity to influence the outcome, marine resource managers have conducted a consultation process which provided stakeholder groups the opportunity to be listened and to comment on the draft plan. However, a consultation process does not assure that all the information provided will be used as part of the decision making process. As such, recreational fishers' expectations that the rezoning process would truly facilitate their participation and reflect their concerns were not supported. Similar to Chapter 4, the lack of trust in the management agency has shaped fishers' perceptions about the reliability of mapping-based information and use of GIS technology. In face of the large extent covered by the rezoning plan, recreational fishers suspected that the closure of fishing grounds would affect their access to marine resources and displace their fishing activity to some extent. However, they believe that the information they provided was used to support the management agency in the selection of the green zones instead of avoiding overlap with fishing areas, since the amount of no-take areas implemented by the plan was greater than initially proposed. Consequently, the implementation and functionality of the management changes established by the rezoning process of the GBRMP has been framed by fishers' dissatisfaction with the consultation process. Nevertheless, the rezoning process has also lead to improved understanding about the conservation values of protecting biodiversity and enhancing sustainability of marine resources and the fisheries it supports.

Although rudimentary and vestigial, a limited PPGIS scenario could be strengthened if key missing linkages are addressed. First, the recreational fishing community, as other stakeholder groups, needs to be engaged at the problem identification phase of the decision making process. By involving the resource users in addressing the question to 'whether the rezoning plan was necessary in the first place', instead of only 'where it would be implemented', would foster ownership of the process and promote trust in the management agency. Second, engaging recreational fishers in the collection and validation of spatially-related information could enhance transparency and ensure more reliability on the analysis and use of collected data. Finally, a continuous and long-term communication about the achievements and limitations of the proposed plan would build and maintain support while minimizing preconceived misconceptions of pre-determined decisions.

Case study 3 (Chapter 6)

Constructs

The adaptive deployment of the spatial sensor network technology characterises a '**functional'** PPGIS scenario (right upper quadrant of Figure 7.1). The early collaboration between technology developers and potential end-users of real-time information during the design stage of the project represents a **latent-active** form of participation. It adopts a participatory design with engagement of coastal managers, from data gathering to information generation, as a core component of the deployment and implementation of the environmental sensor networks in the GBR. In this case, the usage of spatial information and GIS technology is **growing** within the scope the potential end-users activities. Researchers, managers and decision makers have used spatial-based information and technology for water quality monitoring since the establishment of the Marine Park in the 1970s, and the need for high resolution spatial-based has only increased since then due to imminent biodiversity threats caused by climate change. However, it is still not in a mature stage since the acquisition and delivery of real time data are not completely implemented and operational. The core contextual aspects that influence a timely provision and meaningful adoption of real time data and sensor technology to fit into research and management priorities are as follows (Fig. 7.4).

Contextual Factors

Researchers, managers and decision makers require answers that depend on real time spatial data to significantly different questions and timeframes. Whereas researchers want to understand complex processes (e.g. Is there a relationship between suspended sediments (rivers) and turbidity (reef)?) within flexible timeframes, managers are interested in more broader and applied issues (e.g. What long-term changes are likely to occur in coral reef systems as a result of climate change?) while following tight government timelines. It is expected that the adoption of an adaptive and participatory approach for the deployment of sensor network technology in the GBR region will support both management and research requirements. Managers, for instance, will be more prepared to use real time data to respond to complex and uncertain situations because they are learning and exchanging information from the initial stages of the development and implementation of the sensor network technology. This is facilitated by an open organisation structure in which participants are fully engaged from the early stages of the design of the management problem. Management and research institutions were open to participation from the beginning of the technology design stage to end-users participation in outlining the parameters, questions and issues that are necessary to be addressed for a useful application of sensor network data and efficient delivery of real time information. Nevertheless, from the technological point of view, coastal managers believe that the technology might be well ahead of the management needs. Compared to the technical aspects of sensor technology such as data storage, technological issues are not as problematic as the decision-making process in which a policy development has to pass through several stages until it is finally implemented. Emergent sensor network technologies can be readily adapted to management needs if some infrastructure and data management issues are solved but the lack of policy and legal frameworks towards data standards and sharing also needs to be immediately addressed.

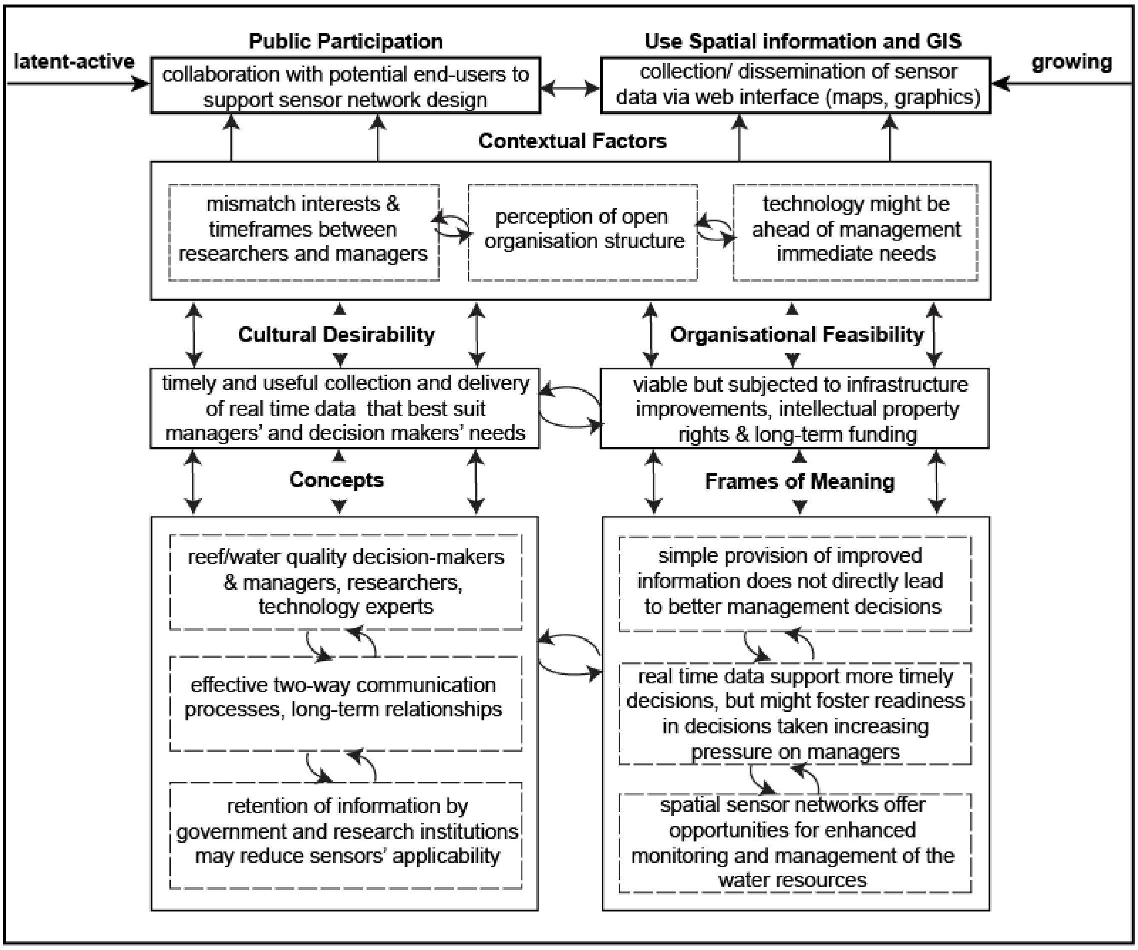

Figure 7.4. Detailed conceptual framework of contextual factors that shape participation and the role of spatial information and GIS in linking science and management in the adoption of sensor network technology along the Great Barrier Reef coast (case study 3).

Cultural Desirability and Organisational Feasibility

It is a consensus between researchers, managers and policy-makers in the GBR that spatial sensor networks offer opportunities for enhanced monitoring and management of the water resources. The collection of useful real time data and timely delivery of information can improve the capability to detect coral bleaching conditions and minimise the continuous decline in the quality of water entering the GBR lagoon. Sensor network technology has, therefore, the potential for monitoring the physical environment in detailed resolutions not currently feasible with existent in situ technology. This is culturally appropriate and environmentally required so water quality parameters (e.g. temperature, salinity, chlorophyll, light, nutrients, water flow rates) can be remotely measured and collected at large spatial coverage and high temporal resolution in a more cost and time effective manner. Organisationally, sensor network technology is feasible and pilot network prototypes have been tested across the GBR. Currently available infrastructure such as reef-based weather stations, communications tower and land-based data server also provide favorable conditions to support collection, process and delivery of a sensor network data (see Fig. 6.1). Nevertheless, some specific architecture conditions (e.g. power management, maintenance and usability, data quality and transmission), lack of long-term investment, shortage of local expertise, inadequate policies towards data standards and sharing still need be addressed so the network and data delivery are fully operational.

Concepts and Frames of Meaning

Despite different needs, the socially relevant groups (the potential public for the sensor network initiative) of this case study represented by reef and water quality managers, decisions makers, researchers and technologists share similar interpretations about the usefulness of emerging spatial technologies for automated intelligent monitoring. In particular, they agree that development of sensor network technology in the GBR needs to be mainly management driven, but with both science and management working in a collaborative way to set the purpose and standards for data collection and analysis. For that, the adaptive management approach proposed by the sensor network initiative needs to support effective two-way communication strategies while improving and maintaining robust relationships those involved in the process. Such relationships are highly dependent on continuous communication processes in which researchers communicate effectively with nonscientists, and managers express their needs for real time data. However, in terms of data sharing, a mutual communication and prompt applicability of real time data is limited by restriction of information by management and research institutions which tend to hold the information for long periods to first develop papers and reports. Data handling and dissemination is framed with the meaning that the provision of raw and unprocessed datasets would cause scientific and political risks. Participants of this case study believe that access of unprocessed data by different users would result in different interpretations of same data which could cause political concern. Therefore, instead of leading to improved management decisions, the provision of real time data would increase pressure on managers and decision managers by fostering public expectations and increasing demand over more readily managed responses to environmental problems. Despite such assumptions and expectations, the adaptive deployment of sensor network technology is highly supported. The early engagement of potential end-users of real time data at the design phase of the project has enhanced understanding about the opportunities and limitations of emerging sensor technology for automated monitoring and improved management of water resources in the GBR.

Although it does not represent a full PPGIS initiative since the sensor network is not at the operational stage, the **'functional'** PPGIS scenario is characterized by a participatory process with the early engagement of both researchers and managers in predicting stakeholders' needs and providing timely and relevant real time information. It represents a promising way in which potential end-users can benefit from the deployment of the sensor network technology by their interests addressed and participation facilitated at early stages of the decision making process.

7.2 Implications of the Research Findings

Theoretical Development, Research and Management

The thesis contributes to general developments in the field of geographical research, particularly PPGIS theory and GIScience. Findings of this research provide relevant information on the social, technological and institutional elements that shape and influence public participation and the context-dependent use of spatial information and GIS tools in NRM in the studied region. In line with the theoretical considerations, the findings of the present research are also relevant for practitioners and managers. This study contributed to the field for by providing an integrated understanding of multiple and realistic case study situations across a complex catchment-to-reef management scale. Given the nascent nature of research in this domain, findings of this study represent only a modest contribution to the existing body of knowledge in the field.

Nevertheless, questions and findings such as those examined by this research provide practical and in-depth information to support a better understanding of the opportunities, constraints, and strategies needed for meaningful participation and use of geographic information and related technology. What is new here is the application of a social constructivist approach to address the mutual influence of social conditions and technology in shaping the issues surrounding public participation and the use of spatial information and GIS within the Australian context.

Findings of this research contribute to the increasing need for in-depth case studies to evaluate people's experience in participation processes as well as the role of GIS and spatial information in support to planning and management processes. This research has demonstrated that the identification of the real needs of users and a realistic understanding of the role of geographic information is critical to achieving an effective utilisation of GIS. The theoretical and practical implications of this research suggest that the use of geospatial tools and spatial information are still not adequately tailored to resource users' immediate needs and maybe, this will not always be possible. Most of the socio-institutional (e.g. disarticulated institutional agendas, limited feedback, perceptions of a top-down driven process, lack of trust in the management agency) and technical constraints (e.g. lack of computer and analytical skills, limited spatial data infrastructure, effectiveness of technologies to manage information, ownership of information and data privacy) are easy to overcome if participation and the use of spatial information and GIS tools are not fully embedded in the decision making process.

Research about the use of spatial information and GIS is considered as important as developing the technology itself. However, most studies have focused on the technological development side instead of its application by different users. This study has also made contributions to the public participation and GIS literature by addressing the gap between theory and practice concerning participatory spatial decision making processes. In doing so, this research has also contributed to an understanding of the mechanisms and dynamics involved in this information delivery rather than simply assuming that spatial information and GIS improve the decision making process.

Finally, findings of this research also support advances in the PPGIS and GIScience literature by developing an integrated conceptual framework that addresses the main aspects surrounding participation and the role of spatial information and GIS based on a realistic understanding of users' needs and the contextual factors that shape such issues within the Australian context.

7.3 Concluding Remarks

Findings from this research address a significant research gap contributing to understanding the extent to which public participation processes and geospatial information (and related GIS tools) have been developed in practice. Overall, findings indicate that a meaningful participation process is directly related to the relevance of the issues involved, the perspectives and interests of participants, and the level of participation aimed to be achieved considering the existing social, organisational and technological contexts.

As stated, this thesis touches on different management contexts (from water quality of coastal resources to rezoning of marine protected areas and innovative spatial sensor technology), several stakeholder's groups (recreational fishers, coastal managers, government agencies, industry, landholders, science providers, and community-based organisations), and a myriad of issues involving public participation and the use of spatial information and GIS. Therefore, a brief summary of major findings of each case study and their contribution to the development of this thesis might prove useful to comprehend the research as a whole.

Chapter 4

This chapter examined the participation strategies and tools used to engage stakeholders in the context of the development of the Burdekin Water Quality Improvement Plan. In doing so, it addressed the extent to which mapping information and spatial technologies had been used to furnish access to information and to support the studied stakeholders' engagement in NRM. Findings of this chapter indicated that, despite stakeholders' interest and motivation to influence decisions regarding land planning and water quality management, their participation has been restricted by instability of NRM staff and extension personnel, tight timelines, short-term funding schemes and lack of timely information. Likewise, an adequate use of spatial data and geographic information technology to support water quality and land use practices is currently limited by uncertainty about data sources, availability of relevant data, lack of technical skills and spatial expertise. Findings also highlight that improved support for water quality management and reductions in land-based pollutant discharges into coastal systems could be enhanced by building trust and strengthening established networks between resource managers and the key stakeholder groups addressed by this research.

Chapter 5

Chapter 5 investigated the extent to which management changes in the rezoning of the marine protected areas in the Great Barrier Reef has affected recreational fishing access to the marine resources and the spatial distribution of fishing effort within the Marine Park in. It analysed fishers' motivations and perceptions of the public participation process and consultation techniques used in the management of fisheries and marine park-related issues. The chapter also addressed the importance and usefulness of spatial data and geographic information tools in reflecting the effects of management changes in the allocation of recreational fishing effort within the Marine Park. Results showed that failure to adequately consider recreational fishers' spatial substitution decisions resulted in a number of negative impacts on recreational fishers (e.g., displaced fishing effort towards inshore areas, increased crowding popular fishing areas) and on the Marine Park (e.g., increased fishing pressure in areas remaining open to recreational fishing and to previously unexploited areas). Findings also indicated that dissatisfaction with the consultation processes, rather than with the outcomes of the rezoning plan, resulted in a low level of trust in the GBRMPA. Despite claims of the management agency that an extensive public education and consultation process was conducted providing opportunities for comment on the draft zoning plans, fishers believed their concerns were not adequately incorporated in the rezoning process. They also believe that the spatial information they provided was misused to support the management agency in the selection of the green zones instead of avoiding overlap with fishing areas. Finally, an early and more structured engagement of fishers in problem identification, design, collection, and validation of spatially-related information is necessary to improve the engagement and incorporation of fishers' concerns in the management of fisheries and marine park planning.

Chapter 6

Chapter 6 assessed the engagement of potential end-users at early stages of the spatial sensor technology development. This chapter addressed the extent to which the deployment of sensor networks and the delivery of real time data can best suit managers' and decision makers' needs by providing timely and useful spatial data. It identified the main drivers and barriers to the deployment of an environmental sensor network along the Great Barrier Reef coast. The chapter also explored the perceptions of sensors' end-users towards participation in coastal and water quality management processes. Findings revealed that the establishment of two-way communication processes and development of long-term relationships are key factors for end-users participation and adoption of real time sensor data. For this reason, participants of this case study recognised that there is a great need for public participation policies to be fully incorporated into science and decision making processes. Improved communication between researchers and decision makers was found to be a critical component in this process. Environmental managers and decision makers need to better communicate their information needs to scientists and technology experts, whereas experts need to better understand and fit management priorities into their research purposes. Another finding of this chapter is that the collection and dissemination of real time data needs to be fit into a well-established purpose and defined context. These findings indicate that data provided by geospatial technologies such as the sensor network needs to be supported by adequate mechanism for information delivery, such as development of a dissemination information plan for the end user, establishment of a system of easy integration of data as well as a collaborative user-friendly web platform for data diffusion.

The proposed analytical framework linked and synthesised the social and technological frames across the case studies providing a coherent framework that integrates the findings of three real NRM situations (catchment, coast and marine systems). The model brings together the needs, constraints, perceptions and assumptions to public participation and the use of spatial information and GIS by key stakeholder groups (recreational fishers, coastal managers, government agencies, industry, landholders, science providers, and community-based organisations) at critical management contexts (water quality, rezoning GBR, and emerging geospatial technologies).

As with any research, it is important to recognize the overall limitations of the study. Some of the limitations related to research design were pointed out earlier in Chapter 3. Others were associated with the particular context on each of the case studies investigated by this research and those were carefully detailed in the respective chapters. Additional limitations were realised in the course of the research and those will be addressed in this section. As noted elsewhere in this thesis, a limitation of this study was that it focused on only a portion of the population. The study was conducted within a limited geographic and socioeconomic region. Another limitation of this research is that findings and suggestions followed the assumption that participation necessarily implies positive outcomes and increased engagement of stakeholders in planning and management processes. However, non-, pseudo or peripheral participation might be desirable in some contexts, particularly in situations which people have no interest in being involved.

From analysing and discussing the results of this research, another important limitation was found. In Chapter 4, for instance, data were collected and analysed through the lens of the public participation ladder and spectrum of public participation, which were the same approaches used in the Water Quality Improvement Plan-Coastal Catchments Initiative Community Communication and Consultation Strategy. Such typologies are based on a unidimensional scale of level of empowerment (from inform to empower) and degrees of access to information. However, such a linear approach may not truly reflect the reality and complexities of the studied context. If a different typology had been used different results might have been achieved.

Despite the limitations inherent in the nature of a PhD thesis and this particular research topic, it is strongly believed that this study provided ground based evidence of the key spatial and non-spatial components that influence a meaningful public participation process and the relevant use of spatial information and GIS technology in the management of catchment and coastal water systems in the tropical coast of the Great Barrier Reef. Overall, public participation is mostly represented by information and consultation processes, and geographic information technology and advanced spatial analysis tools are still used by the 'usual suspects' (e.g. government organisations and research institutions). However, findings revealed that there is potential for improvement if the existing mechanisms and main sources of information are more interactive and supportive of a two-way of participation process. This research demonstrated that, to be a tool to ease the participation journey on the route of natural resource management, spatial information and GIS need to be better tailored to end-user needs. Future research should be directed to understanding the complexities and potentialities of public involvement in spatial-based decision making processes.

7.4 Recommendations for Future Research

While the aims of the current study have been achieved several other important areas requiring exploration have emerged. Specific recommendations for future research were addressed by the case study chapters 4, 5 and 6. Chapter 4 recommends that further studies in NRM would benefit from research using an experimental design, in which control and treatment groups of stakeholders are exposed to different spatial-related information and tools. In chapter 5, finding meaningful ways of better incorporating recreational fishers' spatial knowledge and geographic information tools in the management of fisheries and marine protected areas is suggested a promising topic for future studies. Chapter 6 proposes that further efforts such as the establishment of more structured partnerships (e.g. an Informal Steering Committee Support Group) are highly necessary to enhance communication flow between researchers, managers and technology developers in the adoption of sensor networks and the meaningful use of spatial information.

Overall, the analysis of contextual factors influencing public participation process and how spatial information and related GIS can better support participatory processes are areas of research that require further consideration. As an incipient field and with the ever increasing demand for public participation in environmental decision-making processes all around the world, PPGIS is a research area in expansion. Future efforts to apply and understand PPGIS include differential access to geographic information and technology; public perceptions of space and understanding of the spatial aspects of decision problems; design and presentation of complex spatial datasets and user interfaces; and the multiple contexts (cultural, social, political and technological) of coupled public participation and geographic information.

PPGIS initiatives are context dependent, so it is important to demonstrate the many different variants that shape their effectiveness, sustainability, and participatory practices. Findings of this research provide relevant information on socio-geographic contextual factors that shape how the public participation community is being linked with geographic information systems and technology. In doing so, this research identified that the role of public participation, spatial information and GIS in NRM of the dry tropical coast is framed by a complex myriad of issues involving institutional arrangements, organisational capacity, social and cultural structures and individual relationships. Despite such complexity, most of the current public participation GIS models fall along a continuum and assume a linear and hierarchic spectrum usually ranging from low participation and no access to spatial information and GIS to high levels of participation and access and use of geographic information technology.

The conceptual model proposed in Chapter 7 addresses some of the social and technological complexities influencing the issues surrounding public participation and the use of spatial information and GIS within the Australian context. Rather than a linear approach, the model adopted a more structured and cohesive framework identifying the key drivers, needs and limitations of different stakeholders within the context of the dry tropical coast. In particular, the detailed frameworks acknowledge, for instance, that trust as well as stable and reliable relationships between resource users and managers are core components of public participation GIS practice. Additional research could attempt to further test, apply and refine the conceptual framework using further grounded case studies and similar methods to verify or contest the proposed model. For example, this could be effectively achieved through analysing how control and experiment groups perceive the value and effectiveness of using spatial information and GIS technology and display natural resource data in support of public participation.

Finally, promising directions for further research in the field of psychology could explore the behavioural and cognitive aspects of public perceptions of space and understanding of the spatial aspects of decision making problems. Further studies in cognitive science would benefit and expand GIScience if the factors that affect people’s ability to learn and interpret spatial-based information and related technologies are addressed. The challenge for PPGIS of contributing to the adoption of spatial information and GIS technology and supporting a more inclusive public participation process still remains a task for further research. There is also an increasing need to evaluate the structural and managerial aspects of geo-information (e.g. access, ownership, use rights, maintenance) to define appropriate strategies and mechanisms for integrated applications of geo-spatial technologies and products.

References

Aber, J.S. 2004 History of maps and cartography. Emporia State University. http://academic.emporia.edu/aberjame/map/h_map/h_map.htm.

Akingbade, A., Navarra, D.D. & Georgiadou, Y. (2009). A 10 Years Review and Classification of the Geographic Information Systems Impact Literature (1998-2008). *Nordic Journal of Surveying and Real Estate Research*, 4, 84-116.

Akyildiz, I. F., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: A survey. *Computer Networks*, 38, 393–422.

Ali, H. & Birley, S. (1999). Integrating deductive and inductive approaches in a study of new ventures and customer perceived risk. *Qualitative Market Research: An International Journal*, 2(2), 103-110.

Al-Kodmany, K. (2001). Online tools for public participation. *Government Information Quarterly Journal*, 18, 329-341.

Amaratunga, D. & Baldry, D. (2001). Case study methodology as a means of theory building: performance measurement in facilities management organisations. *Work Study*, 50 (3), 95-104.

Anderson, C., Beazley, K. & Boxall, J. (2009). Lessons for PPGIS from the application of a decision-support tool in the Nova Forest Alliance of Nova Scotia, Canada. *Journal of Environmental Management,* 90, 2081-2089.

Anuchiracheeva, S., Demaine, H., Shivakoti, G.P. & Ruddle, K. (2003). Systematizing local knowledge using GIS: fisheries management in Bang Saphan Bay, Thailand. *Ocean and Coastal Management*, 46, 1049–1068.

ANZECC. (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council, Canberra.

Arnstein, S. (1969). A Ladder of Citizen Participation. *Journal of the American Institute of Planners* 35(4), 216-224.

Asher, W. (2001). Coping with Complexity and Organizational Interests in Natural Resource Management. *Ecosystems*, 4, 742–757.

Aswani, S. & Lauer, M. (2006). Incorporating Fishermen's local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. *Human Organization*, 65(1), 81-102.

Babcock, E.A., Pikitch, E.K., McAllister, M.K., Apostolaki, P. & Santora, C. (2005). A perspective on the use of spatialized indicators for ecosystem-based fishery management through spatial zoning. *ICES Journal of Marine Science*, 62, 469-476.

Bacic, I.L.Z., Bregt, A.K. & Rossiter, D.G. (2006). A participatory approach for integrating risk assessment into rural decision-making: A case study in Santa Catarina, Brazil. *Agricultural Systems*, 87(2), 229-244.

Baelde, P. (2005). Interactions between the implementation of marine protected areas and right-based fisheries management in Austral. *Fisheries Management and Ecology*, 12, 9-18.

Ball, J. (2002). Toward a methodology for mapping ‘regions for sustainability’ using PPGIS. *Progress in Planning*, 58, 81-140.

Balram, S. & Dragićević , S. (2006). *Collaborative Geographic Information Systems* Idea Group Publishing, Hershey, pp. 364.

Balram, S., Dragićević , S. & Feick, R. (2009). Collaborative GIS for spatial decision support and visualisation. *Journal of Environmental Management*, 90(6), 1963–1965.

Bammer, G., O'Connell, D. & Syme, G. (2005). Integration Research for Natural Resource Management in Australia: An Introduction to New Challenges for Research Practice. *Journal of Research Practice*, 1(2), Article E1.

Barnes, M., Newman, J., Knops, A. & Sullivan, H. (2003). Constituting 'the public' in public participation. *Public Administration*, 81(2), 379-399.

Barreteau, O., Bots, P.W.G. & Daniell, K.A. (2010). A Framework for Clarifying “Participation” in Participatory Research to Prevent its Rejection for the Wrong Reasons. *Ecology and Society*, 15(2), 1. [online] URL: http://www.ecologyandsociety.org/vol15/iss2/art1/.

Beierle, T.C. & Konisky, D.M. (2000). Values, Conflict, and Trust in Participatory Environmental Planning. *Journal of Policy Analysis and Management*, 19(4), 587-602.

Bell, D., Gray,T. & Haggett, C. (2005). The‘social gap’in wind farm sitting decisions: explanations and policy responses. *Environmental Politics*, 14, 460–477.

Bellamy, J.A., Walker, D.H., McDonald, G.T. & Syme, G.J. (2001). A systems approach to the evaluation of natural resource management initiatives. *Journal of Environmental Management* 63, 407–423.

Bernard, H.R. (2002). *Research Methods in Anthropology*. 3rd edn, Altamira Press, Wanut Creek, CA.

Biggs, M. (1999). Putting the State on the Map: Cartography, Territory, and European State Formation. *Society for Comparative Study of Society and History*, 374-405.
Bijker, W.E. (1995). *Of Bicycles, Bakelites, and Bulbs - Toward a Theory of Sociotechnical Change.* MIT Press., Cambridge, Massachusetts, pp. 380.
Bijker, W.E., Hughes, T.P. & Pinch, T. (1987). *The Social Construction of Technological Systems.* MIT Press, Cambridge, Massachusetts, pp. 405.
Bijker, W.E. & Law, J. (1992). *Shaping Technology/Building Society - Studies in Sociotechnical Change.* The MIT Press, London, pp. 341.
Bischof, R.J., Zhu, X., Dale, A. & Laredo, L. (1999). Using spatial information in communicative regional resource use planning: A new challenge *The 27th Annual Conference of AURISA,* Blue Mountains NSW, 22-26 November 1999.
Blaschke, T. (2004). Participatory GIS for spatial decision support systems critically revisited. *In* M. Egenhoffer, C. Freksa&H. Miller, (Eds.), *GIScience 2004* Adelphi, MD. pp. 257-261.
Borowski, I., & Hare, M. (2007). Exploring the Gap Between Water Managers and Researchers: Difficulties of Model-Based Tools to Support Practical Water Management. *Water Resources Management*, 21, 1049-1074.
Boulos, M.N.K. (2005). Web GIS in practice III: creating a simple interactive map of England's Strategic Health Authorities using Google Maps API, Google Earth KML, and MSN Virtual Earth Map Control. *International Journal of Health Geographics*, http://www.ij-healthgeographics.com/content/4/1/22.
Brannen, J. (2005). Mixing Methods: The Entry of Qualitative and Quantitative Approaches into the Research Process. *International Journal of Social Research Methodology,* 8(3), 173-184.
Broderick, K. (2007). Burdekin Water Quality Adaptive Management Framework. For the Burdekin Dry Tropics NRM Water Quality Improvement Plan. Prepared by *ARC Centre of Excellence for Coral Reef Studies,* James Cook University. pp.13.
Brodie, J., Christie, C., Devlin, M., Haynes, D., Morris, S., Ramsay, M., et al. (2001). Catchment management and the Great Barrier Reef. *Water Science and Technology,* 43(9), 203-221.
Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A.O. & Hunter, H. (2003). *Sources of sediment and nutrient exports to the Great Barrier Reef World Heritage Area.* Technical Report. Australian Centre for Tropical Freshwater Research, Townsville, Australia.
Brodie, J.E., & Mitchell, A.W. (2005). Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments. *Marine and Freshwater Research*, 56, 279–302.
Bryman, A. (2004). *Social Research Methods*. 2nd edn, Oxford University Press, New York. *Research*, 56, 279–302.
Brooks, A.J. (2006). Digital Moorea: The implementation of a wireless sensor network for the monitoring of coral reefs. *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – Workshop1*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 5th December 2006. (pp. 11-16).
Brugnach, M., Tagg, A., Keil, F.J., & de Lange, W. (2007). Uncertainty Matters: Computer Models at the Science–Policy Interface. *Water Resources Management*, 21, 1075–1090.
Buchy, M., Ross, H. & Proctor, W. (2000). Enhancing the information base on participatory approaches in Australian natural resource management’. *In* Land and Water Australia (Ed.) *Natural Resources Management-People and Policy*. Land and Water Australia, Canberra, pp. 1-78.
Buchy, M. & Race, D. (2001). The Twists and Turns of Community Participation in Natural Resource Management in Australia: What is Missing? *Journal of Environmental Planning and Management,* 44(3), 293-308.
Burdekin Dry Tropics NRM. (2006). Burdekin Dry Tropics Water Quality Improvement Plan - Communication and Consultation Strategy. Burdekin Solutions Ltd, Townsville. pp. 19.
Bush, J., Moffatt, S. & Dunn, C.E. (2001). Keeping the public informed? Public negotiation of air quality information. *Public Understand. Sci.,* 10, 213–229.
Bussink, C. (2003). GIS as a tool in participatory natural resource management - Examples from the Peruvian Andes. *Mountain Research and Development*, 23(4), 320-323.
Butler, D. (2006). The web-wide world. *Nature*, 439, 776-778.
Campbell, H. (1994). How effective are GIS in practice? A case study of British local government. *Int. J. Geographical Information Systems,* 8(3), 309-325.
Campbell, H. & Masser, I. (1995). *GIS and Organizations - How effective are GIS in pratice?* Taylor & Francis, London, UK, pp. 178.

Carver, S., Evans, A., Kingston, R. & Turton, I. (2001). Public participation, GIS, and cyberdemocracy: evaluating on-line spatial decision support systems. *Environment and Planning B: Planning and Design*, 28, 907-921.

Carver, S. (2003). The future of Participatory Approaches Using Geographic Information: developing a research agenda for the 21st Century. J*ournal of the Urban and Regional Information Systems Association (URISA), 15(APA I)*, 61-71.

Chamberlin, J. (2007). Geographic Information Systems and Spatial Information of Rural Development: an introduction to the special issue. *Information Development, 2*3(2/3), 92-95.

Chapin, M., Lamb, Z. & Threlkeld, B. (2005). Mapping Indigenous Lands. *Annu. Rev. Anthropol.*, 34, 619-638.

Chase, L.C., Decker, D.J. & Lauber, T.B. (2004). Public Participation inWildlife Management:What Do Stakeholders Want? *Society and Natural Resources*, 17, 629-639.

Chatterjea, S. & Havinga, P. (2009). Improving Temporal Coverage Of An Energy-Efficient Data Extraction Algorithm For Environmental Monitoring Using Wireless Sensor Networks. *Sensors*, 9(6), 4941-4954.

Chatterjea, S., Kininmonth, S. & Havinga, P. (2006). Sensor Networks. *GEOconnexion International Magazine*, 20-22.

Chrisman, N.R. (1999). What Does 'GIS' Mean? *Transactions in GIS*, 3(1), 175-186.

Chong, C. & Kumar, S.P. (2003). Sensor Networks: Evolution, Opportunities, and Challenges. *Proceedings of the IEEE*, 91(8), 1247-1256.

Cicin-Sain, B. & Knecht, R.W. (1998). *Integrated Coastal and Ocean Management – Concepts and Practice.* Islan Press., Washington, DC., pp. 517p.

Cicin-Sain, B. & Belfiore, S. (2005). Linking marine protected areas to integrated coastal and ocean management: A review of theory and practice. *Ocean & Coastal Management* 48, 847–868.

Cinderby, S. (1999). Geographic information systems (GIS) for participation: the future of environmental GIS? *International Journal of Environment and Pollution*, 11(3), 304-315.

Cinderby, S. & Forrester, J. (2005). Facilitating the local governance of air pollution using GIS for participation. *Applied Geography*, 25(2), 143-158.

Clarke, B. (2006). Australia's Coastcare Program (1995–2002): its Purpose, Components and Outcomes. *Geographical Research*, 44(3), 310-322.

Close, C.H. & Hall, G.B. (2006). A GIS-based protocol for the collection and use of local knowledge in fisheries management planning. *Journal of Environmental Management*, 78(4), 341-352.

Collins, S.L., Bettencourt, L.M.A, Hagberg, A., Brown, R.F., Moore, D.I., Bonito, G., Delin, K.A., Jackson, S.P., Johnson, D.W., Burleigh, S.C., Woodrow, R.R., & McAuley, J. M. (2006). New opportunities in ecological sensing using wireless sensor networks. *Front Ecol Environ*, 4(8), 402–407.

Commonwealth of Australia. (1995). *Living on the Coast: The Commonwealth Coastal Policy*. DEST, Canberra, Australia.

Commonwealth of Australia. (2006), Review of the Great Barrier Reef Marine Park Act 1975. *Review Panel Report*. Department of Environment and Heritage, Canberra.

Commonwealth and Queensland Governments. (2003). *Reef Water Quality Protection Plan Queensland*. Department of Premier and Cabinet, Brisbane.

Connor, D.M. (1988). A new ladder of citizen participation. *National Civic Review*, 77(3), 249-257.

Corbett, J. & Keller, P. (2007). Powering up: community information systems, marginalization and empowerment. G*IS Development Asia Pacific*, 11(2), 30-33.

Coughlin, T., O'Reagain, P. & Nelson, B. (2007). *Review of Current and Proposed Grazing Land Strategies to Improve Water Quality within the Burdekin Catchment-Grazing Land Management for Burdekin Water Quality Outcomes*. Burdekin Solutions Ltd, Townsville. pp. 83.

Coughlin, T., O'Reagain, P., Nelson, B., Butler, B. & Burrows, D. (2008). *Managing for water quality within grazing lands of the Burdekin Catchment- Guidelines for land managers*. Burdekin Solutions Ltd, Townsville. pp. 39.

Cox, M.E., Moss, A. & Smyth, G.K. (2005). Water quality condition and trend in North Queensland waterways. *Marine Pollution Bulletin*, 51, 89-98.

Craig, A. & Vanclay, F. (2005). Questioning the Potential of Deliberativeness to Achieve 'cceptable' Natural Resource Management Decisions. *In* R. Eversole and J. Martin, (Eds.), *Participation and Governance in Regional Development - Global Trends in an Australian Context* (pp. 156-172). Hampshire: Ashgate.

Crampton, J.W. (2001). Maps as social constructions: power, communication and visualisation. *Progress in Human Geography*, 25(2), 235-252.

Creswell, J.W. (2003). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. 2nd edn, Sage, Thousand Oaks, CA.

Croke, B.F.W., Ticehurst, J.L., Letcher, R.A., North, J.P., Newham, L.T.H. & Jakeman, A.J. (2007). Integrated assessment of water resources-Australian experiences. *Water Resour Manage,* 21, 351–373.

Cullen, P. (1997). Science Brokering and Managing Uncertainty. In Great Barrier Reef Marine Park Authority (Ed.), *The Great Barrier Reef: science, use and management*, Nov 25-29 1996, (pp. 309-318). James Cook University, Townsville.

Curtis, A. & Lockwood, M. (2000). Landcare and Catchment Management in Australia: Lessons for State-Sponsored Community Participation. *Society & Natural Resources*, 13, 61-73.

Davidson, E. (2006). A Technological Frames Perspective on Information Technology and Organizational Change *The Journal of Applied Behavioral Science*, 42, 23-39.

Davidson, S. (1998). Spinning the wheel of empowerment. *Planning,*3, 14–15.

Davies, C. & Medyckyj-Scott, D. (1994). GIS usability: recommendations based on user's view *Int. J. Geographical Information Systems*, 8(2), 175-189.

Dalton, T.M. (2005). Beyond Biogeography: a Framework for Involving the Public in Planning of U.S. Marine Protected Areas. *Conservation Biology* 1392-1401.

Davis, A. (2006). *Overview of Research and Environmental Issues relevant to development of Recommended Practices for Sugar Cane Farming in the Lower Burdekin Region*. Burdekin Solutions Ltd, Townsville. pp. 83.

Daw, T.M. (2008). Spatial distribution of effort by artisanal fishers: Exploring economic factors affecting the lobster fisheries of the Corn Islands, Nicaragua. *Fisheries Research*, 90(1-3), 17-25.

Day, J.C. (2002). Zoning - Lessons from the Great Barrier Reef Marine Park. *Ocean & Coastal Management*, 45, 139-156.

Day, J. (2008). EBM Perspective: Correcting Misconceptions about Zoning The Great Barrier Reef Example. *Marine Ecosystems and Management*, pp. 6.

De Freitas, DM. (2006). Report on the Adoption of Sensor Network by Coastal Managers – Workshop 1. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia. 5 December 2006. 44p. [Online available at URL: http:// www.coastalzone.net]

De Freitas, D.M. (2007). Report on the Workshop on the Adoption of Sensor Network by Coastal Managers: An Inshore Water Quality Approach – Workshop 2. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia. 26 July 2007. 31p.[Online available at URL: http:// www.coastalzone.net]

De Freitas, D.M., Kininmonth, & S., Woodley, S. (2007). Sensor Networks for GBRMP Management. *83rd Australian Coral Reef Society Conference*. Fremantle/Australia, 9-11 October 2007.

De Freitas, D.M., Kininmonth, S. & Woodley, S.J. (2009). Linking science and management in the adoption of sensor network technology in the Great Barrier Reef coast, Australia. *Computers, Environment and Urban Systems*, 33, 111-121.

De Freitas, D.M. & Tagliani, P.R.A. (2009). The use of GIS for the integration of traditional and scientific knowledge in supporting artisanal fisheries management in southern Brazil. *Journal of Environmental Management*, 90, 2071–2080.

De Man, W.H.E. (2003). Cultural and Institutional Conditions for Using Geographic Information; Access and Participation. *Journal of the Urban and Regional Information Systems Association (URISA), 15(APA I),* 19-33.

De Man, W.H.E. & van den Toorn, W.H. (2002). Culture and the adoption and use of GIS within organisations. *International Journal of Applied Earth Observation and Geoinformation*, 4(1), 51-63.

Denzin, N.K. & Lincoln, Y.S. (2005). *Handbook of Qualitative Research.* Sage Publications, Thousand Oaks, CA.

Dervin, B. (1998). Sense-making theory and practice: an overview of user interests in knowledge seeking and use. *Journal of Knowledge Management*, 2(2), 36-46.

Devlin, M.J. & Brodie, J. (2005). Terrestrial discharge into the Great Barrier Reef Lagoon: nutrient behavior in coastal waters. *Marine Pollution Bulletin*, 51(1-4), 9-22.

Diacono, J. (2007). Custodianship in Victoria. *Position,* 32: 64-65.

Dight, I. (2009). *Draft Burdekin Water Quality Improvement Plan*. Burdekin Solutions Ltd, Townsville. pp. 136.

Diduck, A. & Sinclair, A.J. (2002). Public Involvement in Environmental Assessment: The Case of the Nonparticipant. *Environmental Management*, 29(4), 578–588.

Dorcey, A., Doney, L. & Rueggeberg, H. (1994) Public Involvement in Government Decision-making: choosing the right model (Victoria, Round Table on the Environment and the Economy).

Dovers, S. (2001). Institutional barriers and opportunities: processes and arrangements for natural resource management in Australia. *Water Science and Technology*, 43(9), 215-226.
Dragićević, S. & Balram, S. (2006). Collaborative geographic information systems: origins, boundaries and structures. *In:* Balram, S., Dragićević , S. (Eds.), *Collaborative Geographic Information Systems*. Idea Group Publishers, Hershey, PA. pp. 1-22.
Drew, C. H. (2003). Transparency – Considerations for PPGIS Research and Development. *URISA Journal,* 15, 73-78.
Drew, J.A. (2005). Use of Traditional Ecological Knowledge in Marine Conservation. *Conservation Biology* 19, 1286-1293.
Duckham, M., Croitoru, A., & Agouris, P. (2007). Theme issue on distributed geoinformatics: From sensors to systems. *ISPRS Journal of Photogrammetry & Remote Sensing*, 62, 325–327.
Dunn, C.E. (2007). Participatory GIS - a people's GIS? *Progress in Human Geography*, 31(5), 616-637.
Elmes, G.A., Epstein, E.L., McMaster, R.B., Niemann, B.J., Poore, B., Sheppard, E., et al. (2005). GIS and Society: Interrelation, Integration, and Transformation. *In* R. B. McMaster & E. L. Usery, (Eds.), *A Research Agenda for Geographic Information Science* Boca Raton, Florida: CRC Press. pp. 287-312.
Elwood, S. (2008). Grassroots groups as stakeholders in spatial data infrastructures: challenges and opportunities for local data development and sharing. *International Journal of Geographical Information Science*, 22(1), 71-90.
Elwood, S. (2009). Geographic information science: emerging research on the societal implications of the geospatial web. *Progress in Human Geography*, 1-9.
Elwood, S. (2010). Thinking Outside the Box: Engaging Critical Geographic Information Systems Theory, Practice and Politics in Human Geography. *Geography Compass* 4/1: 45–60. .
ESRI (Environmental Services Research Incorporated) (2006). ArcMap v. 9.2. Environmental Services Research Incorporated, Redlands, CA.
Everingham, J. (2009). Australia's Regions: Congested Governance or Institutional Void? *Public Policy and Administration*, (24), 84-102.
Eversole, R. & Martin, J. (2005). *Participation and Governance in Regional Development - Global Trends in an Australian Context.* Ashgate, Hampshire, pp. 340.
Fabricius, K.E., De'ath, G., McCook, L., Turak, E. & Williams, D.M. (2005). Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef. *Marine Pollution Bulletin*, 384-398.
Fabricius, K.E., Hoegh-Guldberg, O., Johnson, J., McCook, L., & Lough, J. (2007). Chapter 17 Vulnerability of coral reefs of the Great Barrier Reef to climate change. In Johnson JE and Marshall PA (Eds.), *Climate Change and the Great Barrier Reef. A Vulnerability Assessment* (pp. 515-554). Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.
Falkenmark, M. (2003). Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges. *Phil.Trans. R.Soc. Lond*. B, 358, 2037–2049.
Fan, T. (2006). Large temporal and spatial variation of seawater temperature in coral reefs of southern Taiwan. *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – Workshop1*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 5th December 2006. (pp. 7-11).
Farella, N., Lucotte, M., Louchouarn, P. & Roulet, M. (2001). Deforestation modifying terrestrial organic transport in the Rio Tapajo´s, *Brazilian Amazon. Organic Geochemistry*, 32, 1441-1458.
Fedra, K. & Feoli, E. (1998). GIS technology and spatial analysis in coastal zone management. *EEZ Technology*, 3, 171-179.
Fereday, J. & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), 80-92.
Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., et al. (2005). Establishing Representative No-Take Areas in the Great Barrier Reef: Large-Scale Implementation of Theory on Marine Protected Areas. *Conservation Biology*, 19(6), 1733–1744.
Fernandes, L., Day, J., Kerrigan, B., Breen, D., De'ath, G., Mapstone, B., et al. (2009). A process to design a network of marine no-take areas: Lessons from the Great Barrier Reef. *Ocean & Coastal Management*, 52, 439-447.
Ferreira, M., & Lucius, I. (2007). Converting data into information: understanding the concepts. *EUCC-The Coastal Union*, 16 (3/4), 3.
Finley R. SurveyMonkey [Computer program] 1999. Available http://www.surveymonkey.com/.
Flick, U. (2006). An Introduction to Qualitative Research. 3rd edn, Sage, London.

Fossey, E., Harvey, c., McDermott, F. & Davidson, L. (2002). Understanding and evaluating qualitative research. Australian and New Zealand Journal of Psychiatry 36, 717-732.
Fox, J., Rindfuss, R.R., Walsh, S.J. & Mishra, V. (2002). *People and the environment: Approaches for linking household and community surveys to remote sensing and GIS.* Kluwer Academic Pubs, Boston, pp. 344.
Furnas, M. & Mitchell, A. (2001). Runoff of terrestrial sediment and nutrients into the Great Barrier Reef World Heritage Area. *In:* E. Wolanski (Ed.) *Oceanographic Processes of Coral reefs: Physical and Biological Links in the Great Barrier Reef.* CRC Press, Boca Raton. pp 37-51.
Gal, U. & Berente, N. (2008). A social representations perspective on information systems implementation: Rethinking the concept of "frames". *Information Technology & People*, 21(2), 133-154.
Gentner, B. & Sutton, S. (2008). Substitution in recreational fishing. *In* O. Aas, (Ed.), *Global Challenges in Recreational Fisheries* (pp. 150-169).Oxford, UK: Blackwell Publishing.
Ghose, R. (2007). Politics of scale and networks of association in public participation GIS. *Environment and Planning A* 39(8), 1961-1980.
Ghose, R. & Elwood, S. (2003). Public Participation GIS and Local Political Context: Propositions and Research Directions. *Journal of the Urban and Regional Information Systems Association (URISA)* 15 (APA II), 17-24.
Gichuki, F.N., Liniger, H., MacMillan, L.C., Schwilch, G. & Gikonyo, J.K. (1998). Scarce Water: Exploring Resource Availability, Use and Improved Management. *Eastern and Southern Africa Geographical Journal*, 8, 15-27.
Glasgow, H.B., Burkholder, J.M., Reed, R.E., Lewitus, A.J., & Kleinman, J.E. (2004). Real time remote monitoring of water quality: a review of current applications, and advancements in sensor, telemetry, and computing technologies. *Journal of Experimental Marine Biology and Ecology*, 300, 409-448.
Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. The Qualitative Report 8(4), 597-607.
Goodchild, M.F. (1992). Geographical information science. *International Journal of Information Systems*, 6(1), 31-46.
Goodchild, M.F. (1995). Geographic Information Systems and Geographic Research. *In* J. Pickles, (Ed.), *Ground Truth: The Social Implications of Geographic Information Systems* (pp. 31-50). New York: The Guilford Press.
Goodchild, M.F., Egenhofer, M.J., Kemp, K.K., Mark, D.M. & Sheppard, E. (1999). Introduction to the Varenius project. *Int. J. Geographical Information Science*, 13(8), 731-745.
Gordillo, G. & Andersson, K. (2004). From Policy Lessons to Policy Actions: Motivation to Take Evaluation Seriously. *Public Administration and Development*, 24, 305-320.
Gordon, I.J. (2007). Linking land to ocean: feedbacks in the management of socio-ecological systems in the Great Barrier Reef catchments. *Hydrobiologia*, 591, 25-33.
Goudkamp, K. (2006). Summary of the Great Barrier Reef Marine Park Authority's research and monitoring needs and overlap with a Great Barrier Reef Ocean Observation System (GBROOS). *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – Workshop1*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 5th December 2006. (pp. 37-43).
Grafton, R.Q. & Kompas, T. (2005). Uncertainty and the active adaptive management of marine reserves. *Marine Policy*, 29, 471-479.
Granek, E.F., Madin, E.M.P., Brown, M.A., Figueiras, W., Cameron, D.S., Hogan, Z., et al. (2008). Engaging Recreational Fishers in Management and Conservation: Global Case Studies. *Conservation Biology*, 22(5), 1125-1134.
Gray, D.E. (2004). *Doing Research in the Real World*. Sage, London.
Great Barrier Reef Marine Park Authority. (2007). *Great Barrier Reef Coral Bleaching Response Plan*, 2007-2008. Great Barrier Reef Marine Park Authority, Townsville.
Green, D. (2007). From Data to Information. *EUCC – The Coastal Union*, 16(3/4), 2.
Greiner, R., Herr, A., Brodie, J. & Haynes, D. (2005). A multi-criteria approach to Great Barrier Reef catchment (Queensland, Australia) diffuse-source pollution problem. *Marine Pollution Bulletin*, 51(1-4), 128-137.
Greiner, R., Lankester, A. & Patterson, L. (2007). *Incentives to enhance the adoption of 'best management practices' by landholders: Achieving water quality improvements in the Burdekin River catchment.* Report for the Burdekin Dry Tropics NRM and the Coastal Catchment Initiative (Burdekin). pp. 88.
Greiner, R., Patterson, L. & Miler, O. (2009). Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems*, 99, 86-104.

Gouveia, C., Fonseca, A., Camara, A. & Ferreira, F. (2004). Promoting the use of environmental data collected by concerned citizens through information and communication technologies. *Journal of Environmental Management*, 135-154.

Guston, D.H. (2001). Boundary Organizations in Environmental Policy and Science: An Introduction. *Science, Technology & Human Values*, 26 (4), 399-408.

Haklay, M. (2002). Public Environmental Information Systems: Challenges and Perspectives, University College London (2002).

Haklay, M. (2003). Community participation and geographic information systems. *Environment and Planning B-Planning & Design*, 30(2), 319-320.

Haklay, M. & Tobon, C. (2003). Usability evaluation and PPGIS: towards a user-centred design approach. *International Journal of Geographical Information Science,* 17(6), 577-592.

Haklay, M., Singleton, A. & Parker, C. (2008). WebMapping 2.0: the neogeography of the geoweb. *Geography Compass*, 2, 2011-2039.

Hansen, H.S. & Prosperi, D.C. (2005). Citizen participation and Internet GIS—Some recent advances. *Computers, Environment and Urban Systems*, 29, 617-629.

Hanson, P. C. (2007). A grassroots approach to sensor and science networks. Frontiers in Ecology and the Environment, 5(7) [Guest Editorial].

Hall, B. & Close, C.H. (2007). Local knowledge assessment for a small-scale fishery using geographic information systems. *Fisheries Research*, 83, 11–22.

Hall, G.B., Moore, A., Knight, P. & Hankey, N. (2009). The extraction and utilization of local and scientific geospatial knowledge within the Bluff oyster fishery, New Zealand. *Journal of Environmental Management*, 1-17.

Hajkowicz, S. (2009). The evolution of Australia's natural resource management programs: Towards improved targeting and evaluation of investments. *Land Use Policy*, 26, 471–478.

Hammersley, M. (1992). What's Wrong with Etnography? Routledge, London.

Harley, J.B. (1989). Deconstructing the Map. *Cartographica*, 26(2), 1-20.

Harley, J.B. (1990). Cartography, Ethics and Social Theory. *Cartographica*, 27(2), 1-23.

Harris, T. & Weiner, D. (1998). Empowerment, Marginalization and "Community-integrated" GIS. *Cartography and Geographic Information Systems*, 25(2), 67-76.

Hart, J.K., & Martinez, K. (2006). Environmental Sensor Networks: A revolution in the earth system science? *Earth-Science Reviews*, 78, 177–191.

Harvey, F. & Chrisman, N. (1998). Boundary objects and the social construction of GIS technology. *Environment and Planning A*, 30, 1683-1694.

Harvey, N. & Caton, B. (2003). *Coastal Management in Australia.* Oxford University Press, South Melbourne, pp. 342.

Haynes, D. & Prange, J. (2007). Management drivers for remote sensing and data acquisition and logging at inshore coral reef systems of the GBR.). *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – An Inshore Water Quality Approach - Workshop2*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 26th July 2007. (pp. 9).

Hayward, C., Simpson, L. & Wood, L. (2004). Still left out in the cold: problematising participatory research and development. *Sociologia Ruralis*, 44 (1), 95-108.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., et al. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science,* 318(1737-1742).

Hopley, D., Smithers, S.G. & Parnell, K.E. (2007). *The geomorphology of the Great Barrier Reef.* Cambridge University Press, pp. 546.

Hornby, A.S. (2004). *Oxford Advanced Learner's Dicitionary of Current English*. S. Weihmeier, Ed. Oxford University Press, ed. Sixt Edition.

Hutchings, P., Haynes, D., Goudkamp, K. & McCook, L. (2005). Catchment to Reef: Water quality issues in the Great Barrier Reef Region—An overview of papers. *Marine Pollution Bulletin,* 51(1-4), 3-8.

Hunt, L.M. (2005). Recreational Fishing Site Choice Models: Insights and Future Opportunities. *Human Dimensions of Wildlife*, 10, 153–172.

IAP2. (c) 2007. Spectrum of Public Participation. International Association for Public Participation www.iap2.org.

Innes, J. & Booher, D. (2004). Reframing public participation: strategies for the 21st century. *Planning Theory & Practice*, 5(4), 419 - 436.

Irvin, R.A. & Stansbury, J. (2004). Citizen participation in decision making: Is it worth the effort? *Public Administration Review*, 64(1), 55-65.

Jackson, L.S. (2001). Contemporary Public Involvement: toward a strategic approach. *Local Environment*, 6(2), 135–147.
Jacobs, K., Garfin, G., & Lenart, M. (2005). More than just talk: connecting science and decision making. *Environment*, 47(9), 6-21.
James, D. (2001). *A Community Plan for Natural Resource Management in Townsville-Thuringowa*. Townsville-Thuringowa Landcare Association inc. pp. 70p.
Jankowski, P., Nyergers, T., Smith, A., Moore, T.J. & Horvath, E. (1997). Spatial group choice: a SDSS tool for collaborative spatial decision making. *International Journal of Geographical Information Science*, 11(6), 577-602.
Jankowski, P. & Nyergers, T. (2001). *Geographic Information Systems for Group Decision Making - Towards a participatory geographic information sience.* Taylor & Francis, London, pp. 273.
Jankowski, P. & Nyerges, T. (2003). Toward a Framework for Research on Geographic Information-Supported Participatory Decision-Making. *Journal of the Urban and Regional Information Systems Association (URISA), 15(APA I)*, 9-17.
Jankowski, P., Robischon, S., Tuthill, D., Nyergers, T. & Ramsey, K. (2006). Design Considerations and Evaluation of a Collaborative, Spatio-Temporal Decision Support Systems. *Transactions in GIS,* 10(3), 335-354.
Jankowski, P. & Stasik, M. (1997). Spatial understanding and decision support system: A prototype for public GIS. *Transactions in GIS*, 2(1), 73-84.
Jankowski, P. (2009). Towards participatory geographic information systems for community-based environmental decision making. *Journal of Environmental Management* 90, 1966–1971.
Jasper, F.G.W. (2003). Institutional arrangements for integrated river basin management. *Water Policy*, 5, 77-90.
Jennings, S. & Moore, S.A. (2000). The Rhetoric behind Regionalization in Australian Natural Resource Management: Myth, Reality and Moving Forward. *Journal of Environmental Policy & Planning*, 2, 177-191.
Johnson, B. L. (1999). The role of adaptive management as an operational approach for resource management agencies. Ecology and Society, 3(2), 8. <http://www.consecol.org/vol3/iss2/art8>.
Johnson, D.E. & Dagg, S. (2003). Achieving public participation in coastal zone environmental impact assessment. *Journal of Coastal Conservation* 9, 13-18.
Johnson, J.E. & Marshall, P.A. (editors). (2007). *Climate Change and the Great Barrier* Reef. A *Vulnerability Assessment*. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.
Jonch-Clausen, T. & Fugl, J. (2001). Firming up the Conceptual Basis of Integrated Water Resources Management. *Water Resources Development*, 17(4), 501-510.
Jonsson, A. (2005). Public Participation in Water Resources Management: Stakeholder Voices on Degree, Scale, Potential, and Methods in Future Water Management. *Ambio*, 34(7), 495-500.
Kangas, J. (1995). Supporting the Choice of the Sports Fishing Site. *Journal of Environmental Management* 43, 219-231.
Kliskey, A.D. (1995). The role and functionality of GIS as a planning tool in natural-resource management *Computers, Environment and Urban Systems*, 19(1), 15-22.
Kingston, R., Carver, S., Evans, A. & Turton, I. (2000). Web-based public participation geographical information systems: an aid to local environmental decision-making. *Computers, Environment and Urban Systems*, 24, 109-125.
Kingston, R. 2002. The role of e-government and public participation in the planning process. *Proceedings of XVI AESOP Congress.* 1-14.
Kingston, R. & Smith, R.S., in *WUN GISc PPGIS Seminar Series, October, University of Sheffield, UK*. (2007) pp. http://www.ppgis.manchester.ac.uk/downloads/WUN_GISc_PPGIS_Seminar.pdf.
Kininmonth, S. (2006). Sensor Networks. *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – Workshop1*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 5 December 2006. (pp. 3-6).
Kininmonth, S. (2007). Considerations in establishing environmental sensor networks. In 3rd International conference on intelligent sensors, sensor networks and information (ISSNIP) 2007, Melbourne (pp. 687–691). <http://www. ieeexplore.ieee.org/iel5/4489863/4496790/04496926.pdf?tp=&isnumber= 449 6790&arnumber=4496926>.
Kininmonth, S., Atkinson, I., Bainbridge, S., Woods, G., Gigan, G. & De Freitas, D.M. (2005). The Great Barrier Reef Sensor Network. *Proceedings of PACEM IN MARIBUS XXXI, Townsville, November 2005*.

Kininmonth, S., Bainbridge, S., Atkinson, I., Gilla, E., Barrald, L., & Vidaude, R. (2004). Sensor Networking the Great Barrier Reef. *Spatial Sciences Qld Journal*, Spring 2004, 34-38.

Kirk, J., & Miller, M. L. (1986). Reliability and validity in qualitative research. Beverly Hills, Sage Publications.

Krygier, J. & Wood, D. (2005). *Making Maps: A Visual Guide to Map Design for GIS*. Guilford Publications, New York, pp. 303.

Laituri, M. (1998). Marginal Societies and Geographic Information Systems *Empowerment, Marginalization and Public Participation GIS Meeting.* , Santa Barbara, California 14-17 October 1998.

Lankford, B. & Beale, T. (2007). Equilibrium and non-equilibrium theories of sustainable water resources management: Dynamic river basin and irrigation behaviour in Tanzania. *Global Environmental Change*, 17, 168–180.

Larson, K.L. & Lach, D. (2008). Participants and non-participants of place-based groups: An assessment of attitudes and implications for public participation in water resource management. *Journal of Environmental Management*, 88, 817-830.

Lawrence, R.L. & Deagen, D.A. (2001). Choosing Public Participation Methods for Natural Resources: A Context-Specific Guide. *Society & Natural Resources*, 14, 857-872.

Lawrence, D., Kenchington, R., & Woodley, S. (2002). *The Great Barrier Reef: finding the right balance*. Melbourne University Press, Melbourne.

Leonardi, P.M. & Barley, S.R. (2010). What's Under Construction Here? Social Action, Materiality, and Power in Constructivist Studies of Technology and Organizing. *The Academy of Management Annals,* 4(1), 1-51.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A. & Hugo, G. (2007). Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. *Health & Place*, 111-122.

Lewis, A., Slegers, S., Lowe, D., Muller, L., Fernandes, L. & Day, J. (2003). Use of Spatial Analysis and GIS techniques to Re-Zone the Great Barrier Reef Marine Park. *Coastal GIS Workshop*, University of Wollongong, Australia, July 7-8.

Lewis, S., Brodie, J., Lédée, E. & Alewijnse, M. (2006). *The Spatial Extent of Delivery of Terrestrial Materials from the Burdekin Region in the Great Barrier Reef Lagoon* Australian Centre for Tropical Freshwater Research. pp. 102.

Lewis, S.E., Brodie, J.E., Bainbridge, Z.T., Rohde, K.W., Davis, A.M., Masters, B.L., et al. (2009). Herbicides: A new threat to the Great Barrier Reef. *Environmental Pollution*, 157 (8-9), 2470-2484

Li, S., Ru, Y. & Chang, Z. 2004. Geo-Imagery Bridging Continents. *XXth ISPRS Congress*. Istanbul, Turkey.

Lloret, J., Zaragoza, N., Caballero, D. & Riera, V. (2008). Biological and socioeconomic implications of recreational boat fishing for the management of fishery resources in the marine reserve of Cap de Creus (NW Mediterranean). *Fisheries Research* 91, 252–259.

Lloyd, R. (1999). Organization of feature-, time-, or location-based mental models. *Professional Geographer*, 51(4), 525-538.

Loh, P.K.K., Hsua, W.J., & Pan, Y. (2007). Reliable and efficient communications in sensor networks. *J. Parallel Distrib. Comput,* 67, 922 – 934.

Long, T. & Johnson, M. (2000). Rigour, reliability and validity in qualitative research. *Clinical Effectiveness in Nursing*, 4, 30-37.

Lynam, T., De Jong, W., Sheil, D., Kusumanto, T. & K., E. (2007). A Review of Tools for Incorporating Community Knowledge, Preferences, and Values into Decision Making in Natural Resources *Management. Ecology and Society*, 12(1), 5. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art5/.

Lynch, T.P. (2006). Incorporation of Recreational Fishing Effort into Design of Marine Protected Areas. *Conservation Biology*, 20(5), 1466-1476.

MacEachren, A.M. (2004). *How Maps Work: Representation, Visualisation, and Design*. The Guilford Press, New York, pp. 513.

Mapstone, B., Appleford, P., Broderick, K., Connolly, R., Higgins, J., Hobday, A., et al. (2008). *National Adaptation Research Plan Marine Biodiversity & Resources - Consultation Draft.* National Climate Change Adaptation Research Facility (NCCARF). pp. 53.

Marfo, E. (2008). Institutionalizing citizen participation and community representation in natural resource management: Lessons from the Social Responsibility Agreement negotiation in Ghana. *Community Development Journal*, 43(4), 398-412

Marshall, B.K. & Jones, R.E. (2005). Citizen Participation in Natural Resource Management: does representativeness matter? *Social Spectrum*, 25, 715-737.

Marshall, P. & Schuttenberg, H. (2006). A Reef Manager's Guide to Coral Bleaching. Townsville: Great Barrier Reef Marine Park Authority.

May, J. (2005). *The Triangle of Engagement: An unusual way of looking at the usual suspects*. Community Engagement Unit, The Metropolitan Policy Authority. pp. 18.

McCall, M.K. (2003). Seeking good governance in participatory-GIS: a review of processes and governance dimensions in applying GIS to participatory spatial planning. *Habitat International,* 27, 549–573.

McCall, M.K. (2004). Can Participatory-GIS Strengthen Local-level Spatial Planning? Suggestions for Better Practice *GISDECO 2004*, Skudai, Johor, Malaysia, 10-12 May.

McCall, M.K. & Minang, P.A. (2005). Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. *The Geographical Journal,* 171(4), 340-356.

McCook, L.J., Folke, C., Hughes,T. Magnus, M., Obura, D., & Salm, R. (2007). Chapter 4 Ecological resilience, climate change and the Great Barrier Reef. In Johnson JE and Marshall PA (Eds.), *Climate Change and the Great Barrier Reef.* A *Vulnerability Assessment* (pp. 75-96). Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.

McCulloch, M., Fallon, S., Wyndham, T., Hendy, E., Lough, J. & Barnes, D. (2003). Coral record of increased sediment flux to the inner Great Barrier Reef since European settlement. *Nature,* 421, 727-730.

McMaster, R.B. & Usery, E.L. (2004). *A Research Agenda for Geographic Information Science.* CRC Press, Boca Raton, Florida, pp. 402.

McNie, E.C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science & Policy,* 10, 17-38.

Measham, T.G. (2003). Learning and change in rural regions: understanding influences on sense of place, PhD thesis, The Australian National University, Canberra.

Miller, C.C. (2006). A Beast in the Field: The Google Maps Mashup as GIS/2. *Cartographica*, 41(3), 187-199.

Mitchell, B. (2005). Integrated water resource management, institutional arrangements, and land-use planning. *Environment and Planning A,* 37, 1335-1352.

Mitchell, R.K., Agle, B.R. & Wood, D.J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review*, 22(4), 853-886.

Monaghan, J. (2005) 'Our Way': social space and the geography of land allocation practice on the southern Gulf Lowlands of Cape York Peninsula. PhD thesis, James Cook University.

Moore, S. (2005). Regional Delivery of Natural Resource Management in Australia: Is it Democratic and Does it Matter? *In* R. Eversole & J. Martin, (Eds.), *Participation and Governance in Regional Development - Global Trends in an Australian Context*. Hampshire: Ashgate.

Moore, S.A. & Rockloff, S.F. (2006). Organizing regionally for natural resource management in Australia: Reflections on agency and government. *Journal of Environmental Policy & Planning*, 8(3), 259-277.

Moss, A., Brodie, J. & Furnas, M. (2005). Water quality guidelines for the Great Barrier Reef World Heritage Area: a basis for development and preliminary values. *Marine Pollution Bulletin,* 51, 76-88.

Moss, T. (2004). The governance of land use in river basins: prospects for overcoming problems of institutional interplay with the EU Water Framework Directive. *Land Use Policy,* 1, 85-94.

Murawski, S.A., Wigley, S.E., Fogarty, M.J., Rago, P.J. & Mountain, D.G. (2005). Effort distribution and catch patterns adjacent to temperate MPAs. *ICES Journal of Marine Science*, 62, 1150-167.

Nastasia, B.K. & Schensul, S.L. (2005). Contributions of qualitative research to the validity of intervention research. *Journal of School Psychology*, 43, 177–195.

Ng'ang'a, S.M., Hutchison, M., Vodden, K., Pepper, J., Berry, M., Nichols, S., Sutherland, M., White, R., & Nkwae, B. (2005). *A handbook on issues surrounding linking science and local knowledge in coastal areas – Canadian case studies.* Department of Fisheries and Oceans, Canada.

Nielsen, J.F. (2008). Models of Change and the Adoption of Web Technologies: Encapsulating Participation *The Journal of Applied Behavioral Science* 44, 263-286.

NRMMC. (2006). *National Cooperative Approach to Integrated Coastal Zone Management. Framework and Implementation Plan*. Natural Resource Management Ministerial Council, Canberra.

Nyerges, T. (1993). Understanding the scope of GIS: its relationship to environmental modeling. *In* M. Goodchild, L. Steyaert&B. Parks, (Eds.), *Environmental Modeling with Geographic Information Systems* London Oxford University Press. pp. 75-93.

Nyerger, T., Jankowski, P. & Drew, C. (2002). Data-gathering strategies for social-behavioural research about participatory geographical information systems use. *Int. J. Geographical Information Science*, 16(1), 1-22.

Nyerges, T., Jankowski, P., Tuthill, D. & Ramsey, K. (2006). Collaborative water resource decision support: Results of a field experiment. *Annals of the Association of American Geographers*, 699-725.

Obermeyer, N. (1998). The evolution of public participation GIS. *Cartography and Geographic Information Systems*, 25, 65-66.

OECD. (2001). Information, Consultation and Public Participation in Policy Making. Organisation for Economic Cooperation & Development, Paris.

Oliver, P.E. (2004). Developing Effective Partnerships in Natural Resouces Management, Griffith University (2004).pp. 361p.

Orlikowski, W. (1992). Rethinking the Concept of Technology in Organizations. *Organization Science,* 3(3), 398-427.

Orlikowski, W. & Gash, D. (1994). Technology frames: Making sense of information technology in organizations. *ACM Transactions on Information Systems,* (12), 174-207.

O'Reagain, P.J., Brodie, J., Fraser, G., Bushell, J.J., Holloway, C.H., Faithful, J.W., et al. (2005). Nutrient loss and water quality under extensive grazing in the upper Burdekin river catchment, North Queensland. *Marine Pollution Bulletin*, 51, 37-50.

Orpin, A.R., Ridd, P.V. & Stewart, L.K. (1999). Assessment of the relative importance of major sediment-transport mechanisms in the central Great Barrier Reef lagoon. *Australian Journal of Earth Sciences*, 46, 883–896.

Pahl-Wostl, C. (2007). The Implications of complexity for integrated resources management. *Environmental Modelling & Software*, 22, 561-569.

Paolillo, J., Pimienta, D., Prado, D. & *et al*.,(2005). *Measuring Linguistic Diversity on the Internet.* pp. 109.

Patton, M.Q. (2002). *Qualitative Research and Evaluation Methods*. 3rd edn, Sage Thousand Oaks, CA.

Perkins, C. (2003). Cartography: mapping theory. *Progress in Human Geography*, 27(3), 341-351.

Perkins, C. & Dodge, M. (2009). Satellite imagery and the spectacle of secret spaces. *Geoforum* 40, 546–560.

Petts, J. & Brooks, C. (2006). Expert conceptualisations of the role of lay knowledge in environmental decisionmaking: challenges for deliberative democracy. *Environment and Planning A* 38, 1045-1059.

Pickles, J. (1995). Representations in an Electronic Age-Geography, GIS, and Democracy. *In* J. Pickles, (Ed.), *Ground Truth: The Social Implications of Geographic Information Systems* (pp. 1-30). New York: The Guilford Press.

Pickles, J. (2003). *A History of Spaces: cartography reason, mapping, and the geo-coded world.* Routledge, London, pp. 256.

Pinch, T.J. & Bijker, W.E. (1984). The Social Construction of Facts and Artifacts - Or How The Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science*, 14(3), 339-441.

Pomeroy, R. & Douvere, F. (2008). The engagement of stakeholders in the marine spatial planning process. *Marine Policy*, 32, 816-822.

Portman, M.E. (2007). Zoning design for cross-border marine protected areas: The Red Sea Marine Peace Park case study. *Ocean & Coastal Management* 50, 499–522.

Powers, J.E. & Abeare, S.M. (2009). Fishing effort redistribution in response to area closures. *Fisheries Research*, 99, 216-225.

Prigent, M., Fontenelle, G., Rochet, M.-J.l. & Trenkel, V.M. (2008). Using cognitive maps to investigate fishers' ecosystem objectives and knowledge. *Ocean & Coastal Management* 51, 450-462.

Pyper, W. (2000). Pooling resources. *Ecos,* 105 October-November, 27-29. QSR International (2002). NVivo V.7.0.247.0 SP2. Melbourne, Vic.

Rajasegarar, S., Gubbi, J., Bondarenko, O., Kininmonth, S., Marusic, S., Bainbridge, S., et al. (2008). Sensor Network Implementation Challenges in The Great Barrier Reef Marine Environment ICT-MobileSummit 2008 Conference. Stockholm, Sweden.

Rambaldi, G. & Callosa, j. (2000). *Manual on Participatory 3-Dimensional Modeling for Natural Resource Management. Essentials of Protected Area Management in the Philippines, Vol. 7* NIPAP, PAWB-DENR. pp. 53.

Rambaldi, G. (2005). Who Owns the Map Legend? J*ournal of the Urban and Regional Information Systems Association (URISA)*, 17(1), 5-13.

Rambaldi, G., Kyem, A.P.K., Mbile, P., McCall, M. & Weiner, D. (2005). Participatory Spatial Information Management and Communication in Developing Countries. *Paper presented at the Mapping for Change International Conference (PGIS'05),* , Nairobi, Kenya, 7-10 September 2005.

Rambaldi, G., Kyem, A.P.K., McCall, M. & Weiner, D. (2006). Participatory Spatial Information Management and Communication in Developing Countries. *The Electronic Journal on Information Systems in Developing Countries (EJISDC)*, 25(1), 1-9.

Rao, M. & Murthi, K.R.S. (2006). Keeping up with remote sensing and GI advances- Policy and legal perspectives. *Space Policy*, 22(4), 262-273.

Ravetz, J. (1999). Citizen participation for integrated assessment: new pathways in complex systems. International *Journal of Environment and Pollution*, 11, 331-350.

Reed, M.A., Dougill, A.J. & Baker, T.R. (2008). Participatory Indicator Development: What can ecologists and local communities learn from each other. *Ecological Applications*, 1253-1269.

Reed, M.S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, 141, 2417-2431.

Reef Water Quality Protection Plan, (2003). Environment and Resources Policy. Department of Premier and Cabinet, Brisbane, Australia.

Reeve, D. & Petch, J. (1999). *GIS Organisations and People: A Socio-technical Approach.* Taylor & Francis, Philadelphia, PA, pp. 214.

Reichelt, R.E. (1997). Advances in scientific research on the Great Barrier Reef since 1983. In Great Barrier Reef Marine Park Authority (Ed.), *The Great Barrier Reef: science, use and management,* Nov 25-29 1996, (pp. 9-19). James Cook University, Townsville.

Richards, C., Blackstock, K. & Carter, C. (2007). *Practical Approaches to Participation.* Macaulay Institute, 2004 (2nd edition, 2007), Socio-Economic Research Group (SERG).

Rockloff, S.F. (2003). Organising for Sustainable Natural Resource Management: Representation, Leadership and Partnerships at Four Spatial Scales, PhD thesis, Murdoch University, Murdoch, WA.

Rockloff, S.F. & Lockie, S. (2004). Participatory tools for coastal zone management: Use of stakeholder analysis and social mapping Australia. J*ournal of Coastal Conservation*, 10, 81-94.

Ross, H., Buchy, M. & Proctor, W. (2002). Laying Down the ladder: A Typology of Public Participation in Australian Natural Resource Management. *Australian Journal of Environmental Management*, 9(4), 205-217.

Roth, C.H., Lawson, G. & Cavanagh, D. (2002). *Overview of key Natural Resource Management Issues in the Burdekin Catchment, with particular reference to Water Quality and Salinity - Burdekin Catchment Condition Study Phase I.* Burdekin Dry Tropics Board, CSIRO and the State of Queensland (Department of Natural Resources & Mines). pp. 102p.

Roulet, M., Lucotte, M., Guimaraes, J.R.D. & Rheault, G.I. (2000). Methylmercury in water, seston, and epiphyton of an Amazonian river and its floodplain, Tapaj´os River, Brazil. *The Science of the Total Environment* 261, 43-59.

Roux, D.J., Rogers, K.H., Biggs, H.C., Ashton, P.J., & Sergeant. A. (2006). Bridging the Science-Management Divide: Moving from Unidirectional Knowledge Transfer to Knowledge Interacting and Sharing. *Ecology and Society*, 11(1), 4. [Online available at URL: http://www.ecologyandsociety.org/vol11/iss1/art4/].

Rowe, G. & Frewer, L.J. (2004). Evaluating Public Participation Exercises: A Research Agenda. *Science, Technology, & Human Values,* 29(4), 512-556.

Rowe, G. & Frewer, L.J. (2005). A typology of public engagement mechanisms. *Science Technology & Human Values*, 30(2), 251-290.

Russell, A.W., Vanclay, F.M. & Aslin, J.H. (2010). Technology Assessment in Social Context: The case for a new framework for assessing and shaping technological developments. *Impact Assessment Project Appraisal*, 28(2), 109-116.

Sadagopan, G.D. (2000). Web-Based Geographic Information Systems: Public Participation in Virtual Decision Making Environments, Virginia Polytechnic Institute and State University (2000).pp. 50.

Sahay, S. & Robey, D. (1996). Organizational context, social interpretation, and the implementation and consequences of Geographic information systems. *Accting., Mgmt. & Info. Tech.*, 6(4), 255-282.

Sanchirico, J.N., Cochran, K.A. & Emerson, P.M. (2002). *Marine Protected Areas: Economic and Social Implications.* Resources for the Future. pp. 24.

Sarjakoski, T. (1998). Networked GIS for Public Participation – Emphasis on Utilizing Image Data. *Computer, Environment, and Urban Systems*, 22(4), 381-392.

Savenije, H.H.G. & Van der Zaag, P. (2008). Integrated water resources management: Concepts and issues. *Physics and Chemistry of the Earth,* 33, 290–297.

Sawynok, B. (2007). Marine Protected Areas- stocking the tool box for recreational fishers *National Seminar Brisbane*, Brisbane.

Schlossberg, M. & Shuford, E. (2005). Delineating "Public" and "Participation" in PPGIS. *Journal of the Urban and Regional Information Systems Association (URISA), 16(APA II)*, 15-26.
Scholz, A., Bonzon, K., Fujita, R., Benjamin, N., Woodling, N., Black, P., et al. (2004). Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. *Marine Policy*, 28(4), 335–349.
Seale, C. (2004). Researching Society and Culture. 2nd edn, Sage, London.
Sheaves, M., Brodie, J., Brooke, B., Dale, P., Lovelock, C., Waycott, M., Gehrke, P., Johnston, R., & Baker, R. (2007). Chapter 19 Vulnerability of coastal and estuarine habitats in the Great Barrier Reef to climate change. In Johnson JE and Marshall PA (Eds.), *Climate Change and the Great Barrier Reef.* A *Vulnerability Assessment* (pp.593-620). Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.
Shelby, B. & Vaske, J.J. (1991). Resource and activity susbstitutes for recreational salmon fishing in New Zealand. *Leisure Sciences*, 13, 21-32.
Sieber, R.E. (2003). Public participation geographic information systems across borders. *Canadian Geographer,* 47(1), 50-61.
Sieber, R.E. (2006). Public Participation Geographic Information Systems: A Literature Review and Framework. *Annals of the Association of American Geographers,* 96(3), 491-507.
Silver, J.J. & Campbell, L.M. (2005). Fisher Participation in research: Dilemmas with the use of fisher knowledge. *Ocean & Coastal Management*, 48, 721-741.
Sikor, T. & Lund, C. (2009). Access and Property: A Question of Power and Authority. *Development and Change,* 40(1):1-22.
Silverman, D. (2006). *Interpreting Qualitative Data*. 2nd edn, Sage, London.
Slob, A.F.L., Rijnveld, M., Chapman, A.S., & Strosser, P. (2007). Challenges of linking scientific knowledge to river basin management policy: AquaTerra as a case study. *Environmental Pollution,* 148, 867-874.
Smith, R.S. & Craglia, M. (2003). Digital Participation and Access to Geographic Information: A Case Study of Local Government in the United Kingdom. *Journal of the Urban and Regional Information Systems Association (URISA),* 15(APA II), 49-54.
SPSS (1996) SPSS for Windows: Base System User's Guide. Release 15.0. SPSS Inc. Chicago.
St. Martin, K. (2004). GIS in Marine Fisheries Science and Decision Making. *In* W. L. Fisher&F. J. Rahel, (Eds.), *Geographic Information Systems in Fisheries* Alpharetta, GA: American Fisheries Society.
State Coastal Plan.(2002). The State Coastal Management Plan. Queensland Government.
Steinmann, R., Krek, A. & Blaschke, T. (2005). Can online map-based applications improve citizen participation? *In*, *E-Government: Towards Electronic Democracy* Heidelberg: Springer Berlin.
Stelzenmüller, V., Maynou, F., Bernard, G., Cadiou, G., Camilleri, M., Crec'hriou, R., et al. (2008). Spatial assessment of fishing effort around European marine reserves: Implications for successful fisheries management. *Marine Pollution Bulletin*, 56, 2018-2026.
Stoll, J. & Sunm, M. (2005). Don't Shoot the Messenger: PPGIS and Community Empowerment *URISA 4th Annual Public Participation GIS Conference*, Cleveland, Ohio, USA.
Strauss, A.L. & Corbin, J. (1998). Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. 2nd edn, Sage, Thousand Oaks, CA.
Sui, D.Z. (2008). The wikification of GIS and its consequences: Or Angelina Jolie's new tattoo and the future of GIS. *Computers, Environment and Urban Systems* 32, 1-5.
Sun, M.T., Tsai, Y.T. & Lin, J.Y.W. (2009). Public Participation and the Concept of Space in Environmental governance: An Application of PPGIS. *Public Administration and Development*, 29, 250-261.
Sumaila, U.R., Guenette, S., Alder, J. & Chuenpagdee, R. (2000). Addressing ecosystem effects of fishing using marine protected areas. *ICES Journal of Marine Science*, 57, 752–760.
Suman, D., Shivlani, M. & Milon, J.W. (1999). Perceptions and attitudes regarding marine reserves: a comparison of stakeholder groups in the Florida Keys National Marine Sanctuary. *Ocean & Coastal Management,* 52, 1019-1040.
Sutton, S.G. (2006a). *An assessment of the social characteristics of Queensland's recreational fishers*. CRC Reef Research Centre Technical Report 65. CRC Reef Research Centre. Townsville. pp. 149.
Sutton, S.G. (2006b). Understanding Recreational Fishers' Participation in Public Consultation Programs. *Human Dimensions of Wildlife,* 11(5), 329 - 341.
Sutton, S.G. (2007). Constraints on recreational fishing participation in Queensland, Australia. *Fisheries*, 32(2), 73-83.

Sutton, S.G. (2008). *Recreational fishers' perceptions about the costs and benefits of the 2004 Great Barrier Reef Marine Park Zoning Plan.* Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited. pp. 44.

Sutton, S.G. & Ditton, R.B. (2005). The substitutability of one type of fishing for another. *North American Journal of Fisheries Management*, 25, 536-546.

Sutton, S.G. & Tobin, R.C. (2009). Recreational fishers' attitudes towards the 2004 rezoning of the Great Barrier Reef Marine Park. *Environmental Conservation*, 36(3), 245-252.

Swinford, A., McIntosh, B. & Jeffrey, P. (2002). Designing ICT tools to support participative catchment management processes. *Proceedings of the Marie-Curie conference on 'Science for Water Policy: the implications of the Water Framework Directive*' 2-4 September 2002, Norwich, UK.

Swofford, J. & Slattery, M. (2010). Public attitudes of wind energy in Texas: Local communities in close proximity to wind farms and their effect on decision-making. *Energy Policy*, 38, 2508-2519.

Szaro, R.C., Berc, J., Cameron, S., Cordle, S., Crosby, M., Martin, L., Norton, D., O'Malley, R., & Ruark, G. (1998). The ecosystem approach: science and information management issues, gaps and needs. *Landscape and Urban Planning*, 40, 89-101.

Tang, K.X. & Waters, N.M. (2005). The internet, GIS and public participation in transportation planning. *Progress in Planning* 64(1), 7-62.

Taut, S. & Brauns, D. (2003). Resistance to Evaluation: A Psychological Perspective. *Evaluation*, 9(3), 247-264.

Teh-White, K., Houston, S., Baxter, C., Levine, J. & White, P. (2004) *Great Barrier Reef Marine Park Authority: Enhanced Community Partnerships.* Melbourne, Australia: Futureye Pty. Ltd.

Thomas, D.R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, 27, 237-246.

Thomson, D. & Alisson, J. (2006). Engaging stakeholders in regional NRM practice change. Land & Water Australia. Australian Government.

Thompson, L., Jago, B., Fernandes, L. & Day, J. (2004). *Barriers to communication – how these critical aspects were addressed during the public participation for the rezoning of the Great Barrier Reef Marine Park.* Great Barrier Reef Marine Park Authority, Townsville.

Totlandsdal, A.I., Fudge, N., Sanderson, E.G., van Bree, L., & Brunekreef, B. (2007). Strengthening the science-policy interface: experiences from a European Thematic Network on Air Pollution and Health (AIRNET). *Environmental Science & Policy*, 10, 260-266.

Treby, E.J. & Clark, M.J. 2004. Refining a practical approach to participatory decision making: An example from coastal zone management. *Coastal Management*, 4, 353-372.

Tripathi, N. & Bhattarya, S. (2004). Integrating Indigenous Knowledge and GIS for Participatory Natural Resource Management: State-of-the-Practice. T*he Electronic Journal on Information Systems in Developing Countries (EJISDC)*, 17(3), 1-13.

Trochim WM. 2000. *The Research Methods Knowledge Base.* 2nd edn, Atomic Dog Publishing, Cincinnati, Ohio.

Tulloch, D.L. & Shapiro, T. (2003). The Intersection of Data Access and Public Participation: Impacting GIS Users' Success? *Journal of the Urban and Regional Information Systems Association (URISA), 16(APA II)*, 55-60.

United States Environmental Protection Agency, (1996). *RCRA Public Participation Manual.* Office of Solid Waste, Permits Branch, Washington, DC.

United Nations Conference on Environment and Development (1992). Agenda 21. Retrieved November 2009, from Source: http://www.un.org/esa/dsd/agenda21/res_agenda21_01.

United Nations Economic Commission for Europe. (1998). AARHUS Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters. Retrieved November 2009, from http://www.unece.org/env/pp/.

Vajjhala, S. (2006). "Ground Truthing" Policy, Using Participatory Map-Making to Connect Citizens and Decision Makers. *Resources*, pp. 14-18.

Valcic, B. (2009). Spatial policy and the behavior of fishermen. *Marine Policy*, 33, 215-222.

Vallega, A. (2005). From Rio to Johannesburg: The role of coastal GIS. *Ocean & Coastal Management*, 48(7-8), 588-618.

van der Horst, D. (2007). NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy sitting controversies. *Energy Policy*, 35,2705–2714.

van Loenen, B. (2009). Developing geographic information infrastructures: the role of access policies. *International Journal of Geographical Information Science*, 23(2), 195-212.

Ventura, S.J. (1995). The Use of Geographic Information-Systems in Local-Government. *Public Administration Review*, 55(5), 461-467.

Voss, A., Denisovich, I., Gatalsky, P., Gavouchidis, K., Klots, A., Roeder, S., et al. (2004). Evolution of a participatory GIS. *Computers, Environment and Urban Systems*, 28(635-651).
Walker, D.H. & Johnson, A.K.L. (1996). NRM tools: a flexible decision support environment for integrated catchment management. *Environmental Software*, 11(1-3), 19-24.
Walker, D.H., Johnson, A.K.L., Cottrell, A., O'Brien, A., Cowell, S.G., Pullar, D. (1998). GIS through Community-based Collaborative Joint Venture: an Evaluation of Impacts in Rural Australia. *Paper prepared for the NCGIA Specialist Meeting on ''Empowerment, Marginalization, and Public Participation GIS*.'' Available at: http://bbq.ncgia.ucsb.edu:80/varenius/.
Walker, D.H., Cowell, S.G. & Johnson, A.K.L. (2001). Integrating research results into decision making about natural resource management at a catchment scale. Agricultural Systems, 69, 85-98.
Walker, D.H., Leitch, A.M., de Lai, R., Cottrell, A., Johnson, A.K.L. & Pullar, D. (2002). A community-based and collaborative GIS joint venture in rural Australia. *In* W. J. Craig, T. M. Harries and D. Weiner, (Eds.), *Community Participation and Geographic Information Systems* (pp. 137-152). London: Taylor & Francis.
Walsham, G. (2002). Cross-cultural software production and use: a structuration analysis. *MIS Quarterly*, 26(4), 359–380.
Walsham, G., & Sahay, S. (1999). GIS for district level administrators in India: Problems and opportunities. *MIS Quarterly*, 23(1), 38–66.
Walters, C.J. & Martell, S.J.D. (2004). *Fisheries Ecology and Management*. Princeton University Press, Princeton, New Jersey, pp. 399.
Wanga, X., Yua, Z., Cinderby, S. & Forrester, J. (2008). Enhancing participation: Experiences of participatory geographic information systems in Shanxi province, China. *Applied Geography* 28, 28, 96–109.
Webler, T. & Renn, O. (1995). A Brief Primer on Participation; Philosophy and Pratice. *In* O. Renn, Webler, T. & Wiedemann, P. (Ed.), *Fairness and Competence in Citizen Participation* (pp. 17-33). Dordrecht: Klumer Academic Publishers.
Webler, T., Tuler, S. & Krueger, R. (2001). What is a good public participation process? Five perspectives from the public. *Environmental Management*, 27(3), 435-450.
Weick, K.E., Sutcliffe, K.M. & Obstfeld, D. (2005). Organizing and the process of sensemaking. *Organization Science*, 16(4), 409-421.
Weidemann, I. & Femers, S. (1993). Public participation in waste management decision making: analysis and management of conflicts. *Journal of Hazardous Materials*, 33, 355-368.
Weiner, D. & Harries, T.M. (2003). Community-integrated GIS for Land Reform in South Africa. *Journal of the Urban and Regional Information Systems Association (URISA)*, 15(APA II), 61-73.
Whelan, J. & Oliver, P. (2005). *The place, limits and collaboration: lessons from case studies in community participation in natural resource management*. Griffith University. pp. 63.
White, S.S. (2001). Public participation and organizational change in Wisconsin land use management. *Land Use Policy* 18, 341-350.
Williams, R. & Edge, D. (1996). The Social Shaping of Technology. *Research Policy*, 25, 856-899.
Wilsdon, J., & Willis, R. (2004). *See-through Science - Why public engagement needs to move upstream*. (1st ed.). London: Demos.
Winter, G. (2000). A Comparative Discussion of the Notion of 'Validity' in Qualitative and Quantitative Research. The Qualitative Report, 4(3 & 4), 10p
Wood, D. (1992). The power of maps. New York, Guilford.
Woodley, S. (2006). Science and Natural Resource Policy and Management. *In*: De Freitas, D.M. (ed.), *Report on the Workshop on the Adoption of Sensor Network by Coastal Managers – Workshop1*. School of Earth and Environmental Sciences, James Cook University. Townsville, Australia, 5 December 2006. (pp. 18-26).
Woodley, S., Williams, D.M., Harvey, T. & Jones, S. (2006). *World Heritage Research: Making a Difference. CRC Reef Research, Education and Capacity Building 1999-2006*. CRC Reef Research Centre, Townsville, Australia.
Wooldridge, S., Brodie, J. & Furnas, M. (2006). Exposure of inner-shelf reefs to nutrient enriched runoff entering the Great Barrier Reef Lagoon: Post-European changes and the design of water quality targets. *Marine Pollution Bulletin*, 52(11), 1467-1479.
Wright, D., Duncan, S.L. & Lach, D. (2009). Social Power and GIS Technology: A Review and Assessment of Approaches for Natural Resource Management. *Annals of the Association of American Geographers*, 99(2), 254–272.
Yang, C., Wong, D., Yang, R., Kafatos, M. & Li, Q. (2005). Performance-improving techniques in web-based GIS. *International Journal of Geographical Information Science*, 19(3), 319-342.

Yigitcanlar, T., Baum, S. & Stimson, R. (2003). Analyzing the Patterns of ICT Utilization for Online Public Participatory Planning in Queensland, Australia. *Assessment Journal*, 2006(Spring), 5-20.
Yin, R.K. (1994). Case Study Research: Design and Methods. 2nd edn, Sage, Thousand Oaks, CA.
Yin, R.K. (2003). *Applications of Case Study Research,* Applied Social Research Methods Series. 2nd edn, Sage, Thousand Oaks, CA.
Zhu, X., Healey, R.G. & Aspinall, R.J. (1998). A Knowledge-Based Systems Approach to Design of Spatial Decision Support Systems for Environmental Management. *Environmental Management*, 22(1), 35-48.

The role of public participation, spatial information and GIS in natural resource management of the dry tropical coast, northern Australia

Volume 2

APPENDICES

Débora Martins DE FREITAS
B.App.Sci. (Hons). - MSc. App.Sci. (Hons).
Federal University of Rio Grande - Brazil

JAMES COOK UNIVERSITY
AUSTRALIA

Ethics Approval

JAMES COOK UNIVERSITY Townsville Qld 4811 Australia Tina Langford, Ethics Administrator, Research Office. Ph: 07 4781 4342; Fax: 07 4781 5521

ETHICS REVIEW COMMITTEE **Human Ethics Committee** *APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS*					
PRINCIPAL INVESTIGATOR	**Ms Debora de Freitas**				
SUPERVISORS	A/Prof David King & Dr Alison Cottrell (Tropical Environment Studies & Geography)				
SCHOOL	Tropical Environment Studies & Geography				
PROJECT TITLE	**Strengthening participation in the Great Barrier Reef Costal Zone: Analysis of new interactive tools**				
APPROVAL DATE	31 Aug 2006	**EXPIRY DATE**	31 Jul 2008	**CATEGORY**	1

This project has been allocated Ethics Approval Number with the **following conditions**:	***H***	**2422**

1. All subsequent records and correspondence relating to this project must refer to this number.
2. That there is **NO** departure from the approved protocols unless prior approval has been sought from the Human Ethics Committee.
3. The Principal Investigator **must advise** the responsible Ethics Monitor appointed by the Ethics Review Committee:

- periodically of the progress of the project;
- when the project is completed, suspended or prematurely terminated for any reason;
- if serious or adverse effects on participants occur; and if any
- unforeseen events occur that might affect continued ethical acceptability of the project.

4. In compliance with the National Health and Medical Research Council (NHMRC) *"National Statement on Ethical Conduct in Research Involving Humans"* (1999), it is **MANDATORY** that you provide an annual report on the progress and conduct of your project. This report must detail compliance with approvals granted and any unexpected events or serious adverse effects that may have occurred during the study.

NAME OF RESPONSIBLE MONITOR	Cadet-James, Yvonne
EMAIL ADDRESS:	yvonne.cadetjames@jcu.edu.au
ASSESSED AT MEETING	Date: ***26 Jul 2006***
APPROVED **Associate Professor Peter Leggat** **Chair, Human Ethics Committee**	Date: ***31 Aug 2006***
Tina Langford Ethics Officer **Research Office** Tina.Langford@jcu.edu.au	Date: 5 September 2006

Observation Consent Form

JAMES COOK UNIVERSITY

TOWNSVILLE Queensland 4811 Australia Telephone: (07) 4781 4111

INFORMED CONSENT FORM

- Observation -

PRINCIPAL INVESTIGATOR	*Débora De Freitas*
PROJECT TITLE:	*Strengthening Participation in the Great Barrier Reef Coastal Zone: Analysis of New Interactive Tools*
SCHOOL	*School of Environment Studies and Geography (TESAG)*
CONTACT DETAILS	Debora De Freitas TESAG - James Cook University Townsville, QLD 4811 - Australia Ph: 07 47814705 Email: debora.defreitas@jcu.edu.au

DETAILS OF CONSENT:

It has been agreed among the participants (stakeholders) that Debora De Freitas participate as an 'observer' at this meeting. As part of her PhD research at James Cook University Debora is investigating the role of geographic (spatial) information in public participation. Information about the project and consent have been provided through the research partners (collaborators) and agreed among all participants.

In participating in this meeting the researcher will be gathering information on realistic experience of public participation and how the use of spatial information and innovative technologies (i.e. geographic information and communications systems, sensor networks) has been understood and used by the participants.

Permission will be requested to audio tape, photograph or quote participant's observations.

The researcher is aware that if at any time his/her presence becomes sensitive to participants, he/she will be requested to leave the meeting.

All information provided in this meeting in to be anonymous unless prior consent is sought. Strict measures on use and storage of data will be undertaken to assure this confidentiality. An overall summary of the outcomes will be provided in a report sent to research collaborators and partners and at the beginning of 2009.

CONSENT

The aims of this study have been clearly understood by this institution and explained by all participants.
I know that taking part in this study is voluntary and I am aware that I can stop taking part in it at any time and may refuse to answer any questions.
I understand that any information I give will be kept strictly anonymous and that no names or quotations will be used to identify me with this study without my approval. I have been given a copy of this consent form.

Participants:

☐ Yes ☐ No - are aware of the researcher's identity and study's purpose

☐ Yes ☐ No - have agreed to be photographed

☐ Yes ☐ No - have agreed to be audiotaped

Name: *(printed)*

Job position:

Signature: **Date:**

Interview Consent Form

JAMES COOK UNIVERSITY

TOWNSVILLE Queensland 4811 Australia Telephone: (07) 4781 4111

INFORMED CONSENT FORM

- Interview -

PRINCIPAL INVESTIGATOR	*Débora De Freitas*
PROJECT TITLE:	*Strengthening Participation in the Great Barrier Reef Coastal Zone: Analysis of New Interactive Tools*
SCHOOL	*School of Environment Studies and Geography (TESAG)*
CONTACT DETAILS	Debora De Freitas TESAG - James Cook University Townsville, QLD 4811 - Australia Ph: 07 47814705 Email: debora.defreitas@jcu.edu.au

DETAILS OF CONSENT:

I understand this interview is part of a PhD research at James Cook University on the role of geographic (spatial) information in public participation.
In participating in the interview process I will be asked to discuss issues on coastal management, public participation, and the use of innovative technologies (i.e. geographic information and communications systems, sensor networks).
Participation in this survey is voluntary and all information I give is to be treated as confidential.
This interview will take approximately 30 to 45 minutes to complete.
If permission is requested to audio tape or photograph any interview, I have the right to decline, or if required, have the recording edited.
All information provided will remain confidential and anonymous unless my prior consent is sought. Strict measures on use and storage of data will be undertaken to assure this confidentiality.
An overall summary of the outcomes will be provided in a report sent to research collaborators and partners and at the beginning of 2009.

CONSENT

The aims of this study have been clearly explained to me and I understand what is wanted of me. I know that taking part in this study is voluntary and I am aware that I can stop taking part in it at any time and may refuse to answer any questions.

I understand that any information I give will be kept strictly confidential and that no names or quotations will be used to identify me with this study without my approval. I have been given a copy of this consent form.

I consent to:

☐ Yes ☐ No - have this interview audio recorded

☐ Yes ☐ No - be photographed

☐ Yes ☐ No - be re-interviewed if necessary

☐ Yes ☐ No - attend future group discussions and workshops

☐ Yes ☐ No - be informed and participate on an online collaborative discussion forum to discuss issues on coastal management – public participation – geographic information systems can be debated and added in a pro-active manner,

☐ Yes ☐ No - receive a summary report of the research findings

Name: *(printed)*

Signature:	**Date:**

Group discussion and workshop consent form

JAMES COOK UNIVERSITY

TOWNSVILLE Queensland 4811 Australia Telephone: (07) 4781 4111

INFORMED CONSENT FORM
- Groups discussions/Workshops -

PRINCIPAL INVESTIGATOR	*Débora De Freitas*
PROJECT TITLE:	*Strengthening Participation in the Great Barrier Reef Coastal Zone: Analysis of New Interactive Tools*
SCHOOL	*School of Environment Studies and Geography (TESAG)*
CONTACT DETAILS	Debora De Freitas TESAG - James Cook University Townsville, QLD 4811 - Australia Ph: 07 47814705 Email: debora.defreitas@jcu.edu.au

DETAILS OF CONSENT:

I understand this group discussion/workshop is part of a PhD research at James Cook University about the role of geographic (spatial) information in public participation.

I will be asked to discuss issues on coastal management, public participation, and the use of innovative technologies (i.e. geographic information and communications systems, sensor networks).

I was informed that the researcher cannot assure confidentiality on the issues discussed because all participants present in group discussions/workshops can hear what everyone else says. However, I understand that information provided and discussed in this meeting is to be anonymous.

I was reminded that everyone has the same right to talk and listen and am expected to respect the privacy of other participants. I was also advised that there is no right or wrong points of view and that all opinions are valuable source of information.

My participation in this group discussion/workshop is totally voluntary and will last from a minimum of 1 (one) to a maximum of 2 (two) hours. Permission has been requested to audio tape or photography in any section, however; I have the right to withdraw from the interview at any time and to ask for the recorded information to be edited of any of my comments I am not comfortable staying on the record.

I have been advised that an overall summary of the outcomes will be provided in a report sent to research collaborators and partners and at the beginning of 2009.

I realise this consent form will not be stored with any recorded data, and will be kept in locked cabinet.

CONSENT

The aims of this study have been clearly explained to me and I understand what is wanted of me. I know that taking part in this study is voluntary and I am aware that I can stop taking part in it at any time and may refuse to answer any questions.
I understand that any information I give will be kept as confidential as possible and that no names or quotations will be used to identify me in any publication with this study without my approval. I also understand that in group discussions confidentiality can not be guaranteed. I have been given a copy of this consent form.

I consent to:

☐ Yes ☐ No - have this interview audio recorded

☐ Yes ☐ No - be photographed

☐ Yes ☐ No - be interviewed, if necessary, to explore in-depth issues

☐ Yes ☐ No - attend future group discussions and workshops

☐ Yes ☐ No - be informed and participate on an online collaborative discussion forum

Name: *(printed)*

Signature:	**Date:**

Online survey consent form

JAMES COOK UNIVERSITY

TOWNSVILLE Queensland 4811 Australia Telephone: (07) 4781 4111

INFORMED CONSENT FORM
- Online Survey -

PRINCIPAL INVESTIGATOR	*Débora De Freitas*
PROJECT TITLE:	*Strengthening Participation in the Great Barrier Reef Coastal Zone: Analysis of New Interactive Tools*
SCHOOL	*School of Environment Studies and Geography (TESAG)*
CONTACT DETAILS	Debora De Freitas TESAG - James Cook University Townsville, QLD 4811 - Australia Ph: 07 47814705 Email: debora.defreitas@jcu.edu.au

DETAILS OF CONSENT:
This survey investigates the relationship role of geographic (spatial) information in public participation.

I understand this survey is part of a PhD research at James Cook University and that by participating in this survey I will be asked to discuss issues on coastal management, public participation, and the use of innovative technologies (i.e. geographic information and communications systems, sensor networks).

I was reminded that no guarantee of confidentiality can be assured while data are on the Internet. However, to avoid unintentionally violation of my privacy (for example, by quoting the exact words of participants which can be easily traced by powerful search engines such as Google), I will be contacted to give my explicit consent to be quoted. I also understand that all reported information is to be anonymous. Additionally, a user login and password will be requested to participate in an online discussion forum.

I understand that this research does not involve intrusive questions.

I understand that I may decide to discontinue or withdraw at any time, and that responses to the survey will be confidential. The data will be stored in a secure office on a password protected computer. Data will be analysed so that my individual answers will not be identified with me.

CONSENT

The aims of this study have been clearly understood and I voluntarily agree in taking part is this survey and/or discussion forum. I also understand that no guarantees can be made regarding the interception of data sent via the internet by any third parties. I am aware that by clicking in the button "I agree to participate" I am giving my informed consent in participating in the survey and/or discussion forum.

I would like to be contacted to:

- ☐ be interviewed to explore in-depth issues if necessary
- ☐ personally attend group discussions and workshops

If you have chose to be contacted to contribute in the interviews and/or participate in the group discussions and workshops, please send you contact details to **debora.defreitas@jcu.edu.au.**

Clicking on the link below indicates that I am giving my informed consent:

I consent/agree to participate **I do not consent/agree to participate**

Appendix B

Chapter 4 supporting information (list of documents analysed, meetings observed, interview and survey protocols)

Example of documentation and archival records

Title	Type (i.e. fact sheet, report, online)	Source	Date
Burdekin Water Quality Improvement Plan – Draft for Consultation	report	NQ Dry Tropics Land & Water Solutions (formerly Burdekin Dry NMR)	April 2009
Proceedings of the Burdekin and Black-Ross Water Quality Improvement Plans Workshop	proceedings	Queensland Government Natural Resources and Water	Feb 2008
Best management practices to improve the quality of water leaving irrigated sugarcane farms: Guidelines for the Burdekin region	report	BDTNRM Coastal Catchments Initiative	May 2007
Draft Review of Current and Proposed Grazing Land Best Management Practices for Achieving Water Quality Objectives in the Burdekin Catchment (Grazing Land Management for Burdekin Water Quality Outcomes)	report	Australian Centre for Tropical Freshwater Research	May 2007
Grazing Land Best Management Practices (BMPs) Draft Guidelines	report	Published by Burdekin Solutions Ltd as Burdekin Dry Tropics Natural Resource Management www.bdtnrm.org.au/cci/grazinglands/	May 2007
Burdekin Dry Tropics Water Quality Improvement Plan - Communication and Consultation Strategy	plan	Burdekin Dry Tropics NRM	Dec 2006
Draft Environmental Values for the marine and estuarine areas of the Lower Burdekin region	report	Burdekin Dry Tropics NRM	Nov 2006
Review of arrangements for Regional delivery of Natural resource Management programme	report	Ministerial Reference Group for Future NRM Programme Delivery, Australian Government	Mar 2006
Queensland Water Quality Guidelines	report	Queensland Government Environmental Protection Agency	Mar 2006
Community Participation in Australian Natural Resource Management	report	Land & Water Australia research	July 2001
Burdekin e-Bites (monthly release)	online/e-mail	Burdekin Dry Tropics NRM http://www.bdtnrm.org.au/news/burdekinbites/index.html	Dec2006 –Dec 2008
BBIFMAC Enviro News	online/e-mail	Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc http://www.bbifmac.org.au	Nov 2007 – June 2008
The Creek to Coral Echo	online/e-mail	Townsville City Council http://www.creektocoral.org	June 2007- June2008
Ag17: Developing an integrated small catchment approach to management of pesticides and nutrients in cane systems.	e-mail	Canegrowers Burdekin Ltd	Sept 2007
People, Practice and Policy - A review of social and institutional research: Engaging stakeholders in regional NRM practice change	online	Australian Government Land & Water. www.sirp.gov.au/peoplepratcticepolicy/c2.htm. Last accessed: 28/07/08	Last accessed: 28/07/08

Observation at meetings

Observation – List of attended meetings

Activity	Location	Date	Time (hrs)
Burdekin Dry Tropics Region Water Quality Monitoring Link-up	Thuringowa	20-21/09/07	14
Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC)	Ayr	14/09/07	4
Freshwater Fish Barriers in the Burdekin Dry Tropics Region	Townsville	30/08/07	3
Burdekin Dry Tropics workshop: "The importance of contextual data in NRM"	Townsville	06-07/07/07	7
BBIFMAC General Meeting Friday, Lower Burdekin Landcare Centre	Brandon	29/06/07	4
BDTNRM Coastal Community Group Forum	Townsville	24/06/07	4
Lower Burdekin Water Quality Collective General	Ayr	20/06/07	4
CCI Grazier Workshop	Belyando	31/05/07	4
BDTNRM Landholders Incentives Workshop	Charters Towers	30/05/07	3
BDTNRM Landholders incentives Workshop	Greenvale	26/02/07	3
Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC)	Ayr	23/02/07	4
BDTNRM Satellite Imagery Acquisition Project Workshop	Greenvale	21/02/07	6
BDTNRM Satellite Imagery Acquisition Project Workshop	Ayr	16/02/07	2
Water Quality Improvement Plan (WQIP) – Steering Committee Meeting	Ayr	15/02/07	3
BDTNRM – CCI Environmental Values Project - Burdekin District Sportsfishing Club	Ayr	07/11/06	2
Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC)	Ayr	27/10/06	5
BDTNRM – CCI Environmental Values Project - Lower Burdekin Ski Club - Hutchings lagoon	Ayr	21/10/06	2
BDTNRM – CCI Environmental Values Project - Haughton Catchment Committee	Giru	06/10/06	3
			Σ= 77

Presentation of research proposal at meetings

BBIFMAC General Meeting
Friday, 29th June 2007
9.30am – 12.00pm
Lower Burdekin Landcare Centre, Brandon

A G E N D A

1. Open Meeting (9.30am)
2. Apologies
3. Confirmation of Previous Minutes from General Meeting
   23rd February 2007
   27th April 2007 – Note: Quorum not met, Minutes to be read only
4. Business Arising Out of Minutes
5. Financial Report (9.45am)
6. Correspondence In and Out (9.50am)
7. Business Arising from Correspondence
8. Chair's Report (9.55am)
9. Project Manager's Report (10.10am)
10. **Presentation: Debora De Freitas, PhD Candidate - School of Earth and Environmental Sciences, James Cook University. *Use of Spatial Information and GIS in Natural Resource Management of Burdekin Dry Tropic Coast***
11. Morning Tea (10.45am – 11.00am)
12. Guest Speaker: Bob Osborne, Regional Manager, Greening Australia (11.00am)
    Storing Carbon in the Burdekin – Carbon as an alternative enterprise on your farm
13. General Business
14. Next Meeting – Friday, 31st August 2007
15. Close of Meeting

WATER QUALITY IMPROVEMENT PLAN (WQIP)

Steering Committee Meeting

15th February 2007, 9:15 am
John Hy Peak Room, Burdekin Shire Council
Young Street, Ayr

Draft Minutes

Agenda

1. Matters arising

Chair, Mike Cannon, welcomed new Steering Committee members Mr Don Di Marzio (cane grower representative) and Ms Tracey Jensen (representing Burdekin Shire Council). Ian Dight distributed electronic copies of new documents to all SC members.

Actions: None.

2. Presentation and discussion of WQIP Communication and Consultation Strategy

Dr. Rachel Allen, Manager Community and Engagement, presented the WQIP Communication and Consultation Strategy. Her presentation drew attention to the major elements of the Strategy, including its purpose and underlying principles, the engagement matrix, monitoring and measuring the success of engagement. The main focus of Rachel's presentation was on the key consultation phases, including the workplan tasks that are identified in Appendix 1.

Discussion following the presentation identified the need to make more explicit linkages to other initiatives, including the Reef Water Quality Protection Plan, NRW WQ monitoring and Burdekin Basin draft Water Resource Plan.

Actions: Lex Cogle (NRW) to provide written comments on the draft Strategy.

3. Presentation by Allyson Lankester (ACTFR)

Ally Lankester presented a report entitled "Draft Environmental Values for the marine and estuarine areas of the Lower Burdekin region". She outlined the study objectives, noting that the current stage is focussed on Bowling Green and Upstart Bays and adjacent marine areas, and estuarine reaches of the major rivers and creeks entering the two bays (from Haughton River to Burdekin River). Ally outlined the consultation process that has been undertaken to identify the draft Environmental Values for these areas, presented the findings and drew conclusions, noting that all these areas are considered to be slightly to moderately disturbed. Wider input to the draft Environmental Values report is being sought.

Actions: Ian Dight to actively seek input to the draft Environmental Values Report from a wider range of stakeholders, including relevant State Government departments, local councils and water boards.

4. Briefing by Debora de Freitas (JCU)

Debora de Freitas presented her research program on "The use of Spatial Information to support Public Participation in the management of the Burdekin Dry Tropic Coast". Her research, which is being supported by James Cook University and the BDTNRM, aims to identify the main sources of spatial information and communication tools being used as part of WQIP development, the information and communication strategies being employed, and the extent to which spatial information and GIS tools have been/can be better used to strengthen stakeholders' participation. Key outcomes of Debora's research are a *characterization* of relevant sources of spatial information and communication tools according the different stakeholders and a list of priority information and communication strategies that can better support participation in the Lower Burdekin Dry Tropics collaborative management process.

Actions: None.

5. Briefing on development of an adaptive management framework for water quality improvement in the BDT region

Ian Dight briefed participants on work that is to be undertaken by Dr Kathleen Broderick of JCU, on behalf of the BDTNRM Coastal Catchments Initiative, to develop an adaptive management framework for the WQIP. He drew attention to its role as an overarching framework for monitoring and evaluation of management effectiveness, its linkages to other strategies (modelling, monitoring, integration) and the three (3) overlapping components of the activity: (i) development of a conceptual model; (ii) consultation and engagement with key stakeholders; and (iii) process analysis, evaluation and organizational learning. Ian advised SC members that their involvement in this activity is crucial and that they would be approached by Kathleen to arrange for individual meetings.

Actions: None

6. Next Meeting

The next SC meeting was set for *Thursday, 26th April 2007*. The meeting was closed at 11:50 pm.

Brochure distributed at meetings

Please provide your postal address and/or e-mail address below if you would like to received:

- ☐ **a copy of the results of this study when it has been completed**
- ☐ **a free CD copy with open-source GIS softwares**

____

____

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Your contribution of time to this study is greatly appreciated. Your thoughtful and meaningful input will support the development of more interactive and collaborative mechanisms for the engagement and communication strategies of the BDTNRM.

Thank you for taking the time to participate!

Participate in the Online Discussion Forum of the Coastal Zone Network:

coastal zone net

www.coastalzone.net

Conducted by:

JCU — ees School of Earth and Environmental Sciences

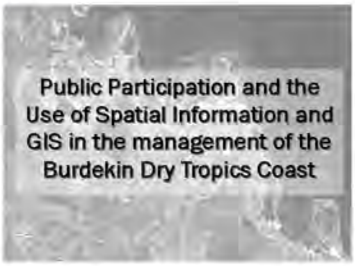
Supported by:

Burdekin Dry Tropics NRM — coastal zone net

If you have any questions please contact:

Débora De Freitas
James Cook University
School of Earth and Environmental Sciences
Angus Smith Drive, QLD 4811
Phone: 07 47814705
E-mail: debora.defreitas@jcu.edu.au

JCU — ees School of Earth and Environmental Sciences



James Cook University - School of Earth and Environmental Sciences
and
Burdekin Dry Tropics NRM

June 2007

Dear Landholder

Introduction

I'm carrying out a study about *'Public Participation and the Use of Spatial Information (e.g. yield mapping, soils types and land information) and GIS in the management of management of natural resources (e.g. water quality, on-farm nutrients management) in the Burdekin Dry Tropic Coast'*.

Community involvement in all aspects of the development of the *Coastal Catchments Initiative (CCI) – Water Quality Improvement Plan (WQIP)* is essential to achieving broad-based ownership of the plan and its successful implementation. The diversity of management issues and participants involved in the development of the Burdekin Dry Tropics (BDT) WQIP demands a deeper understanding of the participation mechanisms and tools necessary to meet water quality targets and to achieve pollutant reductions from land-based sources.

Getting Involved

Many information and communication tools have been deployed without considering the local-based context and users' needs, particularly in the use of mapping information and geographic information tools. Information collected within the scope of the CCI will support future development of more interactive and collaborative mechanisms for the engagement and communication strategies of the BDT WQIP.

A number of options will be available for you give your input , including: face-to-face interview, mail-out questionnaire, phone interview, and online questionnaire. Your participation will require about 30 to 45 minutes of your time.

During the interview, you will be asked to discuss issues about land-use and natural resources management, public participation, and the use spatial (mapping) information and innovative geographic information technologies.

Your participation is totally voluntary and all information you provide is confidential and not identifiable.

If you are interested in participating, please fill in contact details and preferred type of participation below:

1. Name (or an identifier if you like, e.g. *XYOO1*)

____

2. Preferable form of communication:

☐ face-to-face (in person) or ☐ mail-out questionnaire
Please provide address, time and date

____

____

☐ phone
Please provide your contact number, time and date

____

____

☐ online questionnaire
Please provide your email address to be informed when the online version is available:________________

____

3. Could you briefly state (in one/two sentences) what your main interest (s) is in:

a. participation in natural resources management:

____

____

b. spatial data and geographical information tools:

____

____

Interviews

Institution / Sector	Location	Date
Burdekin Dry Tropics NRM / Coastal Catchments Initiative	Townsville	22/03/07
Burdekin Dry Tropics NRM / Coastal Management	Townsville	22/03/07
Burdekin Dry Tropics NRM / Data Management	Townsville	22/03/07
Rural Property Design Services / GIS consultant	Torrens Creek	16/03/07
Townsville City Council / Coral to Creek Program	Townsville	15/05/07
Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc.	Ayr	04/06/07
Conservation Volunteers Australia / Coastal Education	Townsville	07/06/07
Burdekin Shire Council / Environmental & Health Services	Ayr	10/06/07
Department of Primary Industries & Fisheries / Sustainable Production Systems	Townsville	11/06/07
Department of Primary Industries & Fisheries / Reef Plan Extension	Townsville	11/06/07
Coastal Dry Tropics Landcare Inc.	Townsville	14/06/07
Pioneer Cane Growers Organisation	Ayr	21/06/07
Burdekin Productivity Services (BPS) Ltd.	Ayr	26/06/07
Conservation Volunteers Australia / CreekWatch	Townsville	16/07/07
Conservation Volunteers Australia / EnvironFund	Townsville	17/07/07
Greening Australia Queensland Inc.	Townsville	09/08/07
South Burdekin Water Board	Home Hill	12/08/07
Davco Farming	Giru	27/08/07
Canegrowers/ Environmental Officer	Home Hill	11/09/07

Note: * In addition to the formal interview time, most of the key informants were contacted several times during the course of the research.

Agenda and guide protocol of the group discussion session

AGENDA: Let's get together to talk about Public Participation and the use of Mapping Information in the Burdekin Dry Tropics Coast – 14th September, Ayr

PART 1: Identify the drivers and barriers of people's participation in natural resources management (i.e. water quality monitoring, on-farm nutrient)			
	Activity	**Outcome**	**Time**
1.	**Introduction:** explain purpose and desired outcomes of the afternoon.	Group understanding and intro from Debora ***(2 slides of introduc.)*** and Ruth	12:30 (2 mins)
2.	**Ice breaker (Getting to know one another):** All the names in the room and each person says one experience of participation/and or expectations for the afternoon	Know each other and share experiences of participation & identify expectations for the meeting	12:35 (5 mins)
3	**What is public participation?** Inform, consult, involve, collaborate, empower- have this on wall and all move to different areas – write and explore their experiences of this	All participants give examples of each and where they feel most activity has taken place – sentences to describe/give examples of?	12:40 (7 mins)
4	**Begin with ORID (focused conversation)** – For example O – What are current practices? R – What do you feel is working well? R – What do you feel is not working so well? I – Why do you think this is the case? D – see questions below:	Should elicit and list of strengths and weaknesses	12:50 (7 mins)
5	**Consensus Workshop (CW)** "What are the best public participation practices in land and water management in the Burdekin Dry Tropics Coast?" 5.1. first as individuals 5.2. then they join in groups of 3 or 4 5.3. so they identify 'up to 5 key issues' 5.4. and we identify the clusters	A list of 5-7 key ideas that answer the focus question including a list of potential action points underneath	13:00 (50 mins)
Coffee Break (5 mins)			

PART 2: Explore current needs and constraints of spatial data and geographical information tools in the Burdekin Dry Tropics Coast			
	Activity	**Outcome**	**Time**
1.	**Introduction:** explain purpose and desired outcomes of the afternoon.	Group understanding and intro from Debora	13:50 (2 mins)
2.	**Ray's talk:** Enriching Herbert River Community through Collaboration and Innovation	Introduction to open the discussion on spatial-mapping information	13:55 (10 mins)
3	Identify current needs and constraints of spatial data and geographical information tools in the Burdekin Dry Tropics Coast 3.1. in small in groups of 3 or 4	Each participant identify in the provided dartboard sheet their needs and constraints	14:10 (10 mins)

PART 3: Finalizing			
	Activity	**Outcome**	**Time**
1.	Meeting's evaluation	All participants put color dots in the dartboard addressing their satisfaction with the meeting	14:20 (5mins)
2.	Where to from here?	Debora concludes the meeting	14:25 (5mins)

Participation and use of GIS in the management of the Burdekin Dry Tropics

- We need your opinion -

James Cook University
School of Earth and Environmental Sciences

September 2007

Conducted by:

Supported by:

Dear Respondent

A. Introduction

This survey is part of a study about *"Public Participation and the use of Spatial Information (e.g. mapping, geographic information systems) and GIS in the in the management of natural resources in the Burdekin Dry Tropics Coast'* conducted by Débora De Freitas of James Cook University-School of Earth and Environmental Sciences.

Your participation will require about 20 minutes of your time.

In answering the questions, you will be asked to give your opinion on issues about land-use and natural resource management, public participation, and the use of spatial (mapping) information and innovative geographic information technologies.

Your participation is totally **voluntary** and all information you provide is **confidential** and **not identifiable**.

Getting Involved:

Many information and communication tools have been deployed without considering the local-based context and users' needs, particularly in the use of mapping information and geographic information tools. Information gathered within this study will support future development of more interactive and collaborative mechanisms for the engagement and communication strategies in the Burdekin Dry Tropics region.

School of Earth and Environmental Sciences

Participation and use of GIS in the management of the Burdekin Dry Tropics

- We need your opinion -

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September 2007

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School of Earth and Environmental Sciences

Supported by:

BURDEKIN DRY TROPICS NRM
Sustaining our resources

coastal zone.net

Dear Respondent

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B. Public Participation in Natural Resources Management

In Queensland, government and non-government agencies responsible for natural resources management usually realize diverse forms of public participation programs to engage people about land management practices and water quality issues.

1. Overall, do you believe that resource management agencies should consult the public about issues water quality, land management practices or other environmental-related issue?

☐ YES ⟶ *Please skip to '**Question 3**'*

☐ NO ⟶ *Go to '**Question 2'***

2. Please indicate the extent to which you agree or disagree with the following reasons why government agencies *should not* consult the public about natural resources management decisions:

Agencies should not consult the public about natural resource issues because...	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a)...consulting the public is too expensive	1	2	3	4	5
b)...land management and water quality managers know what is best for our natural resources	1	2	3	4	5
c)...the public has little to add to decisions about water quality, land management practices	1	2	3	4	5

....continue Question2

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
d)...it is not possible to incorporate the views of the public in decisions	1	2	3	4	5
e)...consulting the public delays the implementation of important management changes	1	2	3	4	5
f)... consulting the public allows some interest groups to have too much influence in decisions	1	2	3	4	5

NOW GO TO 'Question 3'

3. Have you ever attended a public meeting or made a submission to a government agency (e.g. Department of Natural Resources and Water, Environmental Protection Agency Department Environment Heritage) or a community organization (e.g. Burdekin Dry Tropics NRM) as part of a formal consultation process about a water quality, land management practices or other environmental-related issue?

☐ YES

☐ NO ⟶ *Please skip to '**Question 4'***

a) What was the issue and how did you participate (e.g. attended public meeting, made a formal submission, etc.)?

b) What motivated you to participate?

c) Do you feel your participation was worthwhile? Why or why not?

NOW GO TO 'Question 5'

4. If you *<u>have not</u>* attended a public meeting or made a submission to a government agency:

a) Why have you never become involved in natural resource management issues?

NOW GO TO 'Question 5'

5. How would you define an effective communication and engagement process in natural resources and land-based management issues: (PLEASE TICK ONLY ONE)

An effective communication and engagement process is the one that…..

a)…... keeps me informed about decisions ……………………………… ☐

b)…... keeps me informed, listens to and acknowledge my concerns, providing feedback on how my input influences decisions ……………………………… ☐

c)…... works with me to ensure that. my concerns and issues are directly reflected in the alternatives developed and provides feedback on how my input influences decisions ……………………………… ☐

d)…... looks to me for direct advice in formulating solutions and incorporate my advices and recommendations into to the maximum extent possible ……………………………… ☐

e)…... collectively makes the final decisions, having considered landholders' recommendations ……………………………… ☐

f)…...other (please specify): ……………………………… ☐

6. Please indicate how important you believe each of the elements below is for an effective public engagement in natural resources management issues.

How important is it that public engagement programs…	Not important at all	Slightly Important	Moderately Important	Very Important	Extremely Important
a)...give equal opportunity for all citizens to participate	………….1	2	3	4	5
b)...result in the best outcome for participants	………….1	2	3	4	5
c)...result in the best outcome for the natural resources	………….1	2	3	4	5
d)...result in an outcome that is fair to all affected groups	………….1	2	3	4	5
e)... allow resource managers to express their opinions to citizens	………….1	2	3	4	5
f)... allow citizens to express their opinions to resource managers	………….1	2	3	4	5
g)...give people a genuine opportunity to influence decisions	………….1	2	3	4	5
h)...improve the relationship between resource managers and citizens	………….1	2	3	4	5
i)...do not cost the government too much money	………….1	2	3	4	5
j)...do not require too much time for people to participate	………….1	2	3	4	5
k)...do not cost people too much money to participate	………….1	2	3	4	5
l)...favour the group with the most at stake	………….1	2	3	4	5
m)...allow local concerns to be incorporated into decisions	………….1	2	3	4	5
n)...involve the public at all stages of planning	………….1	2	3	4	5

…..continue Question 6

	Not important at all	Slightly Important	Moderately Important	Very Important	Extremely Important
o)...do not delay the implementation of important management changes	………….1	2	3	4	5
p)...do not allow any one group to have too much influence in decisions	………….1	2	3	4	5
q)... follow a process that is easily understood by everyone	………….1	2	3	4	5

7. Please tell us how useful you think each of the techniques listed below are as a way for the public to participate in natural resources management issues:

	No Useful at all	Moderately Useful	Don't Know	Useful	Very Useful
a) Public meetings	………….1	2	3	4	5
b) Written submissions to the management body	………….1	2	3	4	5
c) Public hearings	………….1	2	3	4	5
d) Public information displays	………….1	2	3	4	5
e) Educational brochures and pamphlets	………….1	2	3	4	5
f) Short summary reports	………….1	2	3	4	5
g) Agency branch offices in local communities	………….1	2	3	4	5
h) Advisory committees	………….1	2	3	4	5
i) Surveys	………….1	2	3	4	5
j) Interactive web sites for submission of comments	………….1	2	3	4	5
k) Toll-free telephone number for submission of comments	………….1	2	3	4	5
l) Volunteer activities	………….1	2	3	4	5
m) Media releases	………….1	2	3	4	5
n) Other (explain)	………….1	2	3	4	5

C. Mapping information and communication tools

The use of spatial information and GIS has increased in natural resources management. Maps of different land uses and vegetation types, and satellite images have been used as a way to aggregate and communicate information. However, such information has been used without considering the local-based context and users' needs.

8. How do you think GIS and spatial information (e.g. Landsat image, vegetation mapping) will help you manage your property?

9. Have you had experience with any mapping software previously?

☐ YES ⟶ ***If yes***, what **software** *(e.g. FarmMap, MapInfo, Phoenix, ArcGIS)* have you used previously? And how did you **acquire the imagery**?

☐ NO ⟶ ***If no***, what was the main reason why you never used mapping software?

10. Please tell us how much do you use each of the following types of maps or mapping tools in the course of your activity (ies):

	No Use	A Little Use	Some Use	Moderate Use	A Lot of Use
a) satellite imagery (e.g. Landsat, Spot5)	1	2	3	4	5
b) geographic information systems	1	2	3	4	5
c) paper maps and/or land use charts	1	2	3	4	5
d) aerial photographs	1	2	3	4	5
e) interactive mapping applications (e.g. Google Earth)	1	2	3	4	5
f) internet maps (e.g. BDTNRM GIS Web, Online Atlas of the NRW)	1	2	3	4	5
g) GPS Photo Link	1	2	3	4	5
h) Other (please explain below):	1	2	3	4	5

11. How would you describe the use of spatial data technologies (i.e. satellite imagery, geographic information systems) in natural resources-land management activities?

a) *Non-existent* (we aren't talking about it and don't have plans) ……………………………… ☐

b) *Conceptual* (just talk at this point but it has not been implemented) ……………………………… ☐

c) *Infancy* (software is provided and we are just starting to use it) ……………………………… ☐

d) *Growing* (we are doing a bit of GIS and our needs are growing) ……………………………… ☐

e) *Mature* (geospatial technology is integral to landholder activities) ……………………………… ☐

f) Other (explain below) ……………………………… ☐

12. Please indicate the extent to which you agree or disagree with the following statements about the use of mapping and geospatial technologies to facilitate public's participation in natural resources planning and management processes:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) spatial information and mapping tools help environmental managers translate and better understand natural resources management issues	1	2	3	4	5
b) lack of skilled staff is a constraint for the use of geospatial tools	1	2	3	4	5
c) geographic information systems are too complex to be used by non-trained users	1	2	3	4	5
d) infrastructure and data accessibility are major problems	1	2	3	4	5
e) software costs are affordable	1	2	3	4	5
f) mapped information increases people's awareness of issues about natural resources management	1	2	3	4	5
g) GIS and satellite imagery create new opportunities for participation in decision-making processes	1	2	3	4	5
h) online mapping tools maximize opportunity for engagement in natural resources issues	1	2	3	4	5
i) other (explain):___________	1	2	3	4	5

D. Follow-up information

This last set of questions is about yourself. We need this information for two reasons:

- *So we can make sure we have include a representative spread of the community.*
- *So we can see if different groups in the community have different opinions and needs.*

13. Are you:

a. ☐ Male ☐ Female

14. What is your age group? (PLEASE TICK ONE)

☐ 20-29 ☐ 50-59
☐ 30-39 ☐ 60-65
☐ 40-49 ☐ >65

15. Education level: (PLEASE TICK AS MANY AS APPLY TO YOU)

☐ No formal schooling
☐ Finished year 6 or less
☐ Finished year 10 or less
☐ Finished year 12 or less
☐ Technical qualification (i.e. TAFE)
☐ Trade/apprenticeship
☐ Work experience (i.e. farming, grazing, mechanical)
☐ Trade/apprenticeship
☐ Tertiary Qualification

16. Which sector do you represent:
(PLEASE TICK AS MANY AS APPLY TO YOU)

☐ sugar cane farming
☐ grazing
☐ horticulture
☐ science
☐ environment management body
☐ non-profit organization
☐ other (please specify): ______________________

E. Additional comments

Is there anything else you would like to share with us?

FEEDBACK!

By returning your completed survey in the post-age-paid return envelope by 25th November 2007 you will receive a copy of the results of this study when it has been completed and a free CD copy with open-source GIS softwares.

I would like to receive a copy of the results of this study and a free CD copy with open-source GIS softwares:

☐ YES → *If yes, please provide your contact details as below.*

☐ NO

Name:

Address:

Phone: Email:

Your contribution of time to this study is greatly appreciated. Your thoughtful and meaningful input will support the development of more interactive and collaborative mechanisms for public participation in natural resources management.

Thank you for taking the time to participate!

Participate in the Online Discussion Forum on Public Participation of the:

wwww.coastalzone.net

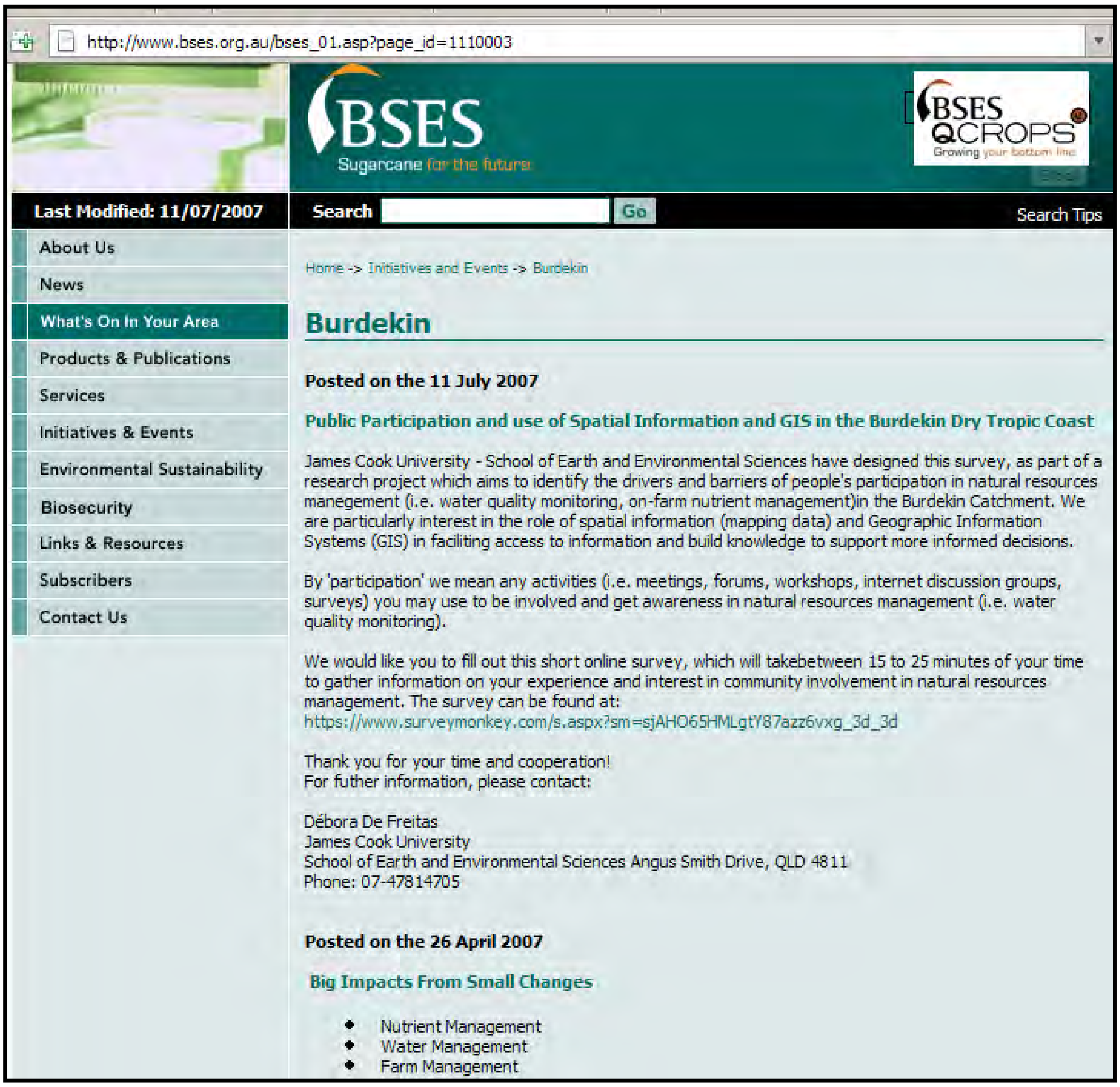
If you have any queries, concerns or comments about this research please contact:

Débora De Freitas
James Cook Universtiy
School of Earth and Environmental Sciences
Angus Smith Drive, QLD 4811
Phone: 07 4781 4705
E-mail: debora.defreitas@jcu.edu.au

School of Earth and Environmental Sciences

If you have any ethical concerns about the way this survey has been conducted, please contact:
Tina Langford
Ethics Administrator,
Research Office, James Cook University
Townsville, QLD 4811
Tel: 07 4781 4342; Fax: 07 4781 5521
Email: Tina.Langford@jcu.edu.au

Online divulgation of research and survey



http://www.bses.org.au/bses_01.asp?page_id=1110003

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Burdekin

Posted on the 11 July 2007

Public Participation and use of Spatial Information and GIS in the Burdekin Dry Tropic Coast

James Cook University - School of Earth and Environmental Sciences have designed this survey, as part of a research project which aims to identify the drivers and barriers of people's participation in natural resources manegement (i.e. water quality monitoring, on-farm nutrient management)in the Burdekin Catchment. We are particularly interest in the role of spatial information (mapping data) and Geographic Information Systems (GIS) in faciliting access to information and build knowledge to support more informed decisions.

By 'participation' we mean any activities (i.e. meetings, forums, workshops, internet discussion groups, surveys) you may use to be involved and get awareness in natural resources management (i.e. water quality monitoring).

We would like you to fill out this short online survey, which will takebetween 15 to 25 minutes of your time to gather information on your experience and interest in community involvement in natural resources management. The survey can be found at:
https://www.surveymonkey.com/s.aspx?sm=sjAHO65HMLgtY87azz6vxg_3d_3d

Thank you for your time and cooperation!
For futher information, please contact:

Débora De Freitas
James Cook University
School of Earth and Environmental Sciences Angus Smith Drive, QLD 4811
Phone: 07-47814705

Posted on the 26 April 2007

Big Impacts From Small Changes

- Nutrient Management
- Water Management
- Farm Management

Summary feedback to participants of the research – Workshop Report

Let's get together to talk about Public Participation and the use of Mapping Information in the Burdekin Dry Tropics Coast

James Cook University's School of Earth and Environmental Sciences with the support of BBIFMAC realized an interactive workshop to discuss **issues about public participation in natural resources management** and the use **of spatial (mapping) information and geographic information systems.**

The meeting happened on the 14th of September at the Haller Summit Conference Room, 15 Queen Street Ayr, from 12.30 – 2.30pm, immediately after the the BBIFMAC Inc (Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc.).

The main purpose of the workshop was to:

- identify the drivers and barriers of people's participation in natural resources management (i.e. water quality monitoring, on-farm nutrient management), and
- understand the current needs and constraints of spatial data and geographical information tools in the Burdekin Dry Tropics Coast.

A total of 18 participants including Farmers, Graziers, non-government organisations (e.g. BDTNRM, Greening Australia, BBIFMAC, Canegrowers) and government organizations (e.g) DPI, and independent consultants, made the workshop an enjoyable and productive time.

Some results of the workshop are presented below.

What is public participation?

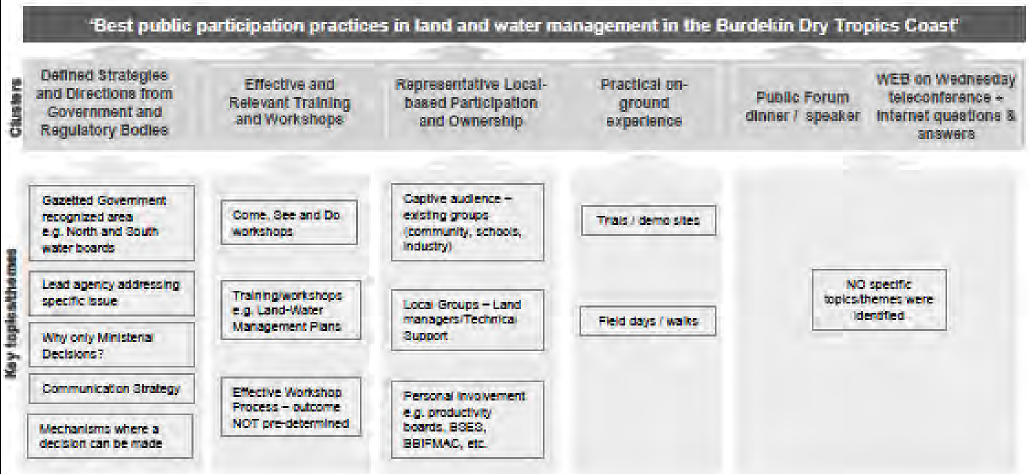
In the first activity of the workshop participants were provided with different examples of public participation activities and they placed the examples describing practical examples according to the following framework:

After sharing an understanding of the different levels and tools used in public participation, participants were guided in an openly focused discussion eliciting a list of strengths and weaknesses of public participation practices in land and water management in the Burdekin Dry Tropics Coast.

Participants worked individually and in groups to list 5-7 key ideas that answer the focus question including the list of potential action points underneath.

Topics and themes identified by the participants as exemples of best and/or potential public participation practices are summarized below:

Workshop participants exploring participation levels and tools. (From left to right: Graeme Porter, Sarah Connor, Ray Menkens and Bob Osborne).



Spatial (mapping) data and geographical information tools

This section of the workshop was opened by a short presentation of Raymond De Lai (the Centre Manager of the Herbert Resource Information Centre (HRIC), Ingham).

Raymond shared with the participants some insights about the role of the HRIC as a collaborative initiative that enriched the Herbert River Community through collaboration and innovation.

Issues about the importance of collaboration, data sharing and privacy, and people's trust were explored. As Raymond mentioned: *"If you feel too small to make a difference, it is because you never have a night alone with a mosquito!"*

In this second part of the workshop, participants identified needs, priorities, sources, benefits and constraints of spatial (mapping) data and GIS tools.

Participants identifying needs, sources, benefits and constraints of spatial information. (From left to right: Graeme Porter, Reg Hugston, Maria Lange and Stuart McCubben).

> ***"It is necessary to get an understand what is technical and what someone can do. There is lots of technical knowledge, but no practical experience.... not related to the circumstances to what we are doing .... technical things don't go on the ground."***
>
> (Workshop's participant)

CDS of mapping and GIS open source softwares provided for the participants.

'Which and how much spatial data is needed':

Group	Needs	Priority	Sources	Benefits	Constraints
1	• registered plan boundaries 1:2500 • paddock boundaries 1:2500 • water courses 1:2500 • state owned roads/easements 1:2500	High Medium Medium Low	BSC, CSR, CSIRO, JCU, DRW, DE, Geoscience Australia, DPI, EPA, North BWB, South BWB	• provide a map to the harvester contractor/fertilizer contractor • safety – showing powerlines, water courses, neighboring, crops, etc • strategic planning	• costs • don't know where to get them from
2	• central access portal	High	Council, BDTB, BSES, CSR	• easy access (single point)	• fragmented sources
3	• cadastral hydrology (e.g. groundwater, levels, pH) • soil types • crop type • soil carbon bores • historic data development	High High High High Medium	Council, EPA, CSIRO, BDTNRM	• land capability • improved agriculture • reduced environmental impact • aid to decision making	• layering info • data ownership (privacy) • mapping data at too course scale • lack of accessibility • data availability (not published)
4	• tree density • location of weeds • working dot ecosystems • soil mapping contours	High High High High	EPA, DNW, BDTNRM, GA	• priority management plan • applications for funding and clearance • location of infrastructure	• satellite imagery poor quality • capacity of internet access • skills of operator

Note: Priority Levels varied from high (75-100), medium (50-75), and low (<50).

What is next?

Feedback gathered from this meeting will used as part of a PhD research project. It will also be used as the basis for the development of non-technical handbook/guidelines to be provided to natural resources management bodies.

Thanks

I would like to thank all the participants for their time and insightful information. I also want to thank *Tom McShanne, Linda Kirk and Graeme Porter* for all the logistic support for the organisation of the workshop.

PARTICIPATE!

Use the online forum of the CoastalZone.Net project to share your experiences of participation in natural resources management.

An online survey exploring issues of public participation and use of spatial information and GIS is also available at the CoastalZone.net. You can fill the survey anonymously, and you just have to provide your contact details if you want to receive a free CD copy with mapping and GIS open source softwares!

www.coastalzone.net

A PDF version of this bulletin can also be downloaded from the CoastalZone.Net website.

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Conducted by:
JCU
ees School of Earth and Environmental Sciences

Supported by: BRIFMAC

Appendix C

Chapter 5 supporting information (semi-structured interview and questionnaire protocols, descriptive statistical tables of distance values)

CapReef Recreational Fisher INTERVIEW Protocol – Data sheet A

CapReef Recreational Fisher Survey

Date:______________ **Id:**______________

Gen: M F

A. Fishing participation

1. How often did you go fishing in the last 12 months?
    1. Weekly or more often
    2. Fortnightly
    3. Once a month
    4. Less often or on holidays

2. How many days in total did you go fishing in the past 12 months? __________

3. How many years have you been fishing recreationally? ___________

4. Compared to other outdoor activities that you participate in (like golf, tennis, camping, etc.), would you say fishing is:
    1. Your most important activity
    2. Your second most important activity
    3. Your third most important activity
    4. Only one of many activities

B. Current fishing locations (for this section and section C, information about fishing locations will be recorded on GBR zoning maps)

5. Please mark on the map your most important saltwater fishing locations/areas within the GBR (these could be your favourite locations, the places where you fish the most, the places where you catch the most fish, etc.).

6. For each location/area marked:
    - How often do you fish there?
    - What species do you target/catch there?
    - Are there any particular reasons why you like to fish there? (i.e., high catch rates, accessibility, target species, lack of other fishers, etc.)

C. Previous/lost fishing locations

The Great Barrier Reef Marine Park has recently undergone a major change with the implementation of a new zoning plan. Under this plan, the amount of 'no-take' areas (i.e., green zones) in the Marine Park was increased from 5% to 33% of the total park area, and the amount and locations of yellow zones was also changed. With these next few questions, we would like to get some idea how these changes in zoning have affected your fishing activity.

7. Are there any locations/areas where you used to fish regularly but now can't because they

8. For each location/area:
    - How often did you used to fish there?
    - What species did you catch/target there?
    - Is there any particular reason why you liked to fish there?

9. For the locations you have lost due to rezoning:
    - Have you replaced the lost areas with any new areas that you had not fished previously? If so, where are the new areas (mark on map)?
    - Have you compensated for the lost areas by fishing more at other areas that you used to fish previously? If yes, where are these areas (mark on map)?
    - Has loss of these areas caused you to target/catch different species? If yes, which ones?
    - Are there any other ways in which you have compensated for or adjusted to the loss of these fishing areas?

10. Are there any other ways in which the rezoning of the Marine Park has affected your fishing activity (positively or negatively)?

D. Attitudes towards rezoning

11. Thinking about the rezoning of the Marine Park, do you think it was a:
    1. Very good idea
    2. Good idea
    3. Neither
    4. Bad idea
    5. Very bad idea

12. What is your level of approval of the number of green zones in the areas where you fish?
    1. Strongly approve
    2. Approve
    3. Neither approve nor disapprove
    4. Disapprove
    5. Strongly disapprove

    12b. In what way do you approve/disapprove of the number of green zones?

13. What is your level of approval of the size of green zones in the areas you fish?
    1. Strongly approve
    2. Approve
    3. Neither approve nor disapprove
    4. Disapprove
    5. Strongly disapprove

    13b. In what way do you approve/disapprove of the size of green zones?

14. What is your level of approval of the location of green zones in the areas you fish?
   1. Strongly approve
   2. Approve
   3. Neither approve nor disapprove
   4. Disapprove
   5. Strongly disapprove

14b. In what way do you approve/disapprove of the location of green zones?

15. What is your level of approval of the number of yellow zones in the areas you fish?
   1. Strongly approve
   2. Approve
   3. Neither approve nor disapprove
   4. Disapprove
   5. Strongly disapprove

15b. In what way do you approve/disapprove of the number of yellow zones?

16. What is your level of approval of the size of yellow zones in the areas you fish?
   1. Strongly approve
   2. Approve
   3. Neither approve nor disapprove
   4. Disapprove
   5. Strongly disapprove

16b. In what way do you approve/disapprove of the size of yellow zones?

17. What is your level of approval of the location of yellow zones in the areas you fish?
   1. Strongly approve
   2. Approve
   3. Neither approve nor disapprove
   4. Disapprove
   5. Strongly disapprove

17b. In what way do you approve/disapprove of the location of yellow zones?

18. Do you agree or disagree that the concerns of recreational fishers were adequately considered in the rezoning process?
   1. Strongly agree
   2. Agree
   3. Neither agree nor disagree
   4. Disagree
   5. Strongly disagree

19. Do you have any suggestions as to how the concerns of recreational fishers could have been better represented in the rezoning process?

20. Are there any aspects of the zoning plan that you would like to see changed?

F. Changes in fishing activity

21. Over the past three years, has your level of fishing activity increased, decreased, or stayed about the same?
   1. Decreased a lot
   2. Decreased a little
   3. Stayed the same
   4. Increased a little
   5. Increased a lot

   If increased or decreased, why?

22. Over the past three years, has your level of satisfaction with fishing increased, decreased, or stayed about the same?
   1. Decreased a lot
   2. Decreased a little
   3. Stayed the same
   4. Increased a little
   5. Increased a lot

   If increased or decreased, why?

23. Over the past three years, has the quality of fishing in your area increased, decreased, or stayed the same?
   1. Decreased a lot
   2. Decreased a little
   3. Stayed the same
   4. Increased a little
   5. Increased a lot

   If increased or decreased, why?

24. Over the past three years, has the amount of money it costs you to go fishing increased, decreased, or stayed about the same?
   1. Decreased a lot
   2. Decreased a little
   3. Stayed the same
   4. Increased a little
   5. Increased a lot

   If increased or decreased, by how much? Why?

G. Participation in fisheries consultation

25. Do you believe that resource management agencies (like the Queensland Department of Primary Industries and Fisheries or GBRMPA) should consult the public about issues affecting recreational fishing?

If yes, Why?

If No, Why not?

26. Have you ever attended a public meeting or made a submission to a government agency (e.g., Queensland Department of Primary Industries and Fisheries, GBRMPA) as part of a formal consultation process about a fisheries- or marine park-related issue?

1. Yes
2. No

If yes:

a. What was the issue and how did you participate (i.e., attended public meeting, made a formal submission, etc.).
b. Did your participation involve the use of maps to collect information from you?
c. What motivated you to participate?
d. Do you feel your participation was worthwhile? Why or why not?

If no:

e. Why have you never become involved in fisheries-related issues?

27. How much do you use each of the following types of maps or mapping tools in the course of your fishing activity?

	No Use	A little use	Moderate use	A lot of use
a. Paper maps and / or nautical charts	1	2	3	4
b. GPS	1	2	3	4
c. Chart plotter	1	2	3	4
d. Aerial photographs	1	2	3	4
e. Internet maps (e.g., Google earth)	1	2	3	4
f. GBR zoning maps	1	2	3	4
g. Geographic Information Systems (GIS)	1	2	3	4
h. Interactive mapping applications	1	2	3	4

(i.e. Coastal Habitat Resources Information System – CHRIS;
GBRMPA GIS Zoning maps
Deep Blue mapping tool)

For each of the tools listed above that you use (i.e. scored 2 or above), what is the reason you use it (i.e., what kind of information are you looking for from each one (e.g., depth, shoreline structure, submerged structure, navigation information, etc))?

For each of the tools listed above that you do not use (i.e. scored 1), why don't you use it?

a. Paper maps and / or nautical charts
b. GPS
c. Chart plotter
d. Aerial photographs
e. Internet maps
f. GBR zoning maps
g. GIS
h. CHRIS

28. Earlier we went through the exercise where we recorded information about the changes in your fishing activity due to the RAP using maps of the GBR. On a scale of 1 to 5 (where 1 = not well at all; and 5 = extremely well), how well do you think we have recorded the spatial changes in your fishing activity due to the RAP?

Not well at all		Moderately well		Extremely well
1	2	3	4	5

If 1 or 2, why?

a. Do you have any concerns about collecting information from you in this way?

29. Have you ever used geographic information systems (GIS) or related geospatial technologies outside fishing?

If Yes:

a. Which purpose?
b. Do you see any way geographical information systems can help you better engage in fisheries management issues?

CapReef Recreational Fisher Survey – Data sheet B

Id:______ **CURRENT (C) and PREVIOUS (P) fishing locations** *(notes to accompany map)*

Location # C1/P1	Location # C2/P2
• How often do you fish there? ______________ • What species do you catch/target there? • Is there any particular reason why you like to fish there? New location (Q9)? _____ (tick) Fish more since rezoning (Q10)? ______ (tick) If yes, how often used to fish there? _______	• How often do you fish there? ______________ • What species do you catch/target there? • Is there any particular reason why you like to fish there? New location (Q9)? _____ (tick) Fish more since rezoning (Q10)? ______ (tick) If yes, how often used to fish there? _______
Location # C3/P3	**Location # C 'n'/P 'n'**
• How often do you fish there? ______________ • What species do you catch/target there? • Is there any particular reason why you like to fish there? New location (Q9)? _____ (tick) Fish more since rezoning (Q10)? ______ (tick) If yes, how often used to fish there? _______	• How often do you fish there? ______________ • What species do you catch/target there? • Is there any particular reason why you like to fish there? New location (Q9)? _____ (tick) Fish more since rezoning (Q10)? ______ (tick) If yes, how often used to fish there? _______

MAIL SURVEY form

Great Barrier Reef Marine Park Recreational Fishing Survey

CONDUCTED BY:

Fishing and Fisheries Research Centre
James Cook University

Most of the questions in this survey are about recreational fishing in the Great Barrier Reef Marine Park. The Great Barrier Reef Marine Park consists of marine waters from the shoreline to beyond the edge of the reef from Bundaberg to the tip of Cape York. Creeks and rivers are <u>not</u> included in the Marine Park.

1. In the last 12 months, how many *days* did you go fishing (including line fishing, spear fishing, crabbing and prawning) in:

   _____ the Great Barrier Reef Marine Park from a boat
   _____ the Great Barrier Reef Marine Park from the shore
   _____ waters outside of the Great Barrier Reef Marine Park (including freshwater)

2. In the last 12 months, how many days did you do each of the following in the Great Barrier Reef Marine Park

   _____ Spear fishing
   _____ Crabbing
   _____ Prawning
   _____ Line fishing

3. Overall, how satisfied are you with fishing in the Great Barrier Reef Marine Park?

	Not at all Satisfied	Slightly Satisfied	Moderately Satisfied	Very Satisfied	Extremely Satisfied
Barrier Reef Marine Park?	1	2	3	4	5

4. Compared to other recreation activities that you do in the Great Barrier Reef Marine Park (such as boating, diving, swimming, etc.), would you say fishing is:

   1 Your most important Great Barrier Reef Marine Park activity
   2 Your second most important Great Barrier Reef Marine Park activity
   3 Your third most important Great Barrier Reef Marine Park activity
   4 Only one of many Great Barrier Reef Marine Park activities

5. How many years have you been fishing in the Great Barrier Reef Marine Park?

   _____ Years

6. What species do you most prefer to catch when fishing in the Great Barrier Reef Marine Park?

   ____________________ Most preferred species
   ____________________ Second most preferred species
   ____________________ Third most preferred species

7. Please indicate the extent to which you agree or disagree with each of the following statements about recreational fishing:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) If I stopped fishing, I would probably lose touch with a lot of my friends	1	2	3	4	5
b) If I couldn't go fishing, I am not sure what I would do	1	2	3	4	5
c) Because of fishing, I don't have time to spend participating in other leisure activities	1	2	3	4	5
d) Most of my friends are in some way connected with fishing	1	2	3	4	5
e) I consider myself to be somewhat of an expert at fishing	1	2	3	4	5
f) I find that a lot of my life is organised around fishing	1	2	3	4	5
g) Others would probably say I spend too much time fishing	1	2	3	4	5
h) I would rather go fishing than do almost anything else	1	2	3	4	5
i) Other leisure activities don't interest me as much as fishing	1	2	3	4	5

In 2004, the Great Barrier Reef Marine Park Authority implemented a new zoning plan for the Great Barrier Reef Marine Park. The aim of the 2004 Zoning Plan was to increase the level of protection given to marine life in the Park. To help accomplish this, the 2004 Zoning Plan increased the amount of Green Zones (i.e., no-take areas) from 5% to 33% of the total Park area, and also changed the amount and location of Yellow Zones (i.e., limited fishing areas) in the Park. With the following questions we are interested in finding out what you think about the 2004 Zoning Plan, and what were the positive and negative effects of the Plan on your fishing activity.

8. How familiar are you with the new Great Barrier Reef Marine Park Zoning Plan that was implemented in 2004?

1 Not at all familiar
2 Vaguely familiar
3 Somewhat familiar
4 Very familiar

9. Please think back to when the new Zoning Plan was first implemented in 2004. In general, how supportive of the plan were you at that time?

1 Strongly supportive
2 Somewhat supportive
3 Neutral
4 Somewhat opposed
5 Strongly opposed
6 Don't know / Not applicable

10. Thinking back to when the new Great Barrier Reef Zoning Plan was about to be implemented in 2004, what effect did you *expect* the new Zoning Plan to have on:

	Strongly Decrease	Slightly Decrease	No effect	Slightly Increase	Strongly Increase	Don't know / Not applicable
a) The number of fish you catch	1	2	3	4	5	6
b) The size of fish you catch	1	2	3	4	5	6
c) Your overall satisfaction with recreational fishing	1	2	3	4	5	6
d) The total amount of time you spend fishing	1	2	3	4	5	6
e) The frequency with which you go fishing	1	2	3	4	5	6
f) The cost ($) of going fishing	1	2	3	4	5	6
g) The number of people fishing in areas of the Marine Park that remain open to fishing	1	2	3	4	5	6
h) Your ability to access quality fishing areas in the Marine Park	1	2	3	4	5	6
i) Your level of knowledge about the Marine Park and its management	1	2	3	4	5	6
j) The protection of marine life in the Park	1	2	3	4	5	6

11. In general, how supportive of the 2004 Great Barrier Reef Zoning Plan are you today?

1 Strongly supportive
2 Somewhat supportive
3 Neutral
4 Somewhat opposed
5 Strongly opposed
6 Don't know / Not applicable

12. Please tell us your opinion about the *amount of area covered* by each of these different types of zones in the area of the Great Barrier Reef Marine Park where you usually fish

	Way too Little	A bit too Little	Just Enough	A bit too Much	Way too Much	Don't know / Not applicable
a) Green Zones (no fishing)	1	2	3	4	5	6
b) Yellow Zones (limited fishing – one line and one hook only)	1	2	3	4	5	6
c) Olive Zones (buffer zones, limited fishing - trolling only)	1	2	3	4	5	6
d) Orange Zones (scientific research – no fishing)	1	2	3	4	5	6
e) Pink Zones (preservation zones – no entry)	1	2	3	4	5	6
f) Dark Blue Zones (habitat protection – no trawling)	1	2	3	4	5	6

Great Barrier Reef Marine Park Recreational Fishing Survey — Page 4

13. Overall, what effect has the 2004 Great Barrier Reef Zoning Plan had on:

	Strongly Decreased	Slightly Decreased	No effect	Slightly Increased	Strongly Increased	Don't know / Not applicable
a) The number of fish you catch	1	2	3	4	5	6
b) The size of fish you catch	1	2	3	4	5	6
c) Your overall satisfaction with recreational fishing	1	2	3	4	5	6
d) The total amount of time you spend fishing	1	2	3	4	5	6
e) The frequency with which you go fishing	1	2	3	4	5	6
f) The cost ($) of going fishing	1	2	3	4	5	6
g) The number of people fishing in areas of the Marine Park that remain open to fishing	1	2	3	4	5	6
h) Your ability to access quality fishing areas in the Marine Park	1	2	3	4	5	6
i) Your level of knowledge about the Marine Park and its management	1	2	3	4	5	6
j) The protection of marine life in the Park	1	2	3	4	5	6

14. Are there any other ways in which the 2004 rezoning of the Great Barrier Reef Marine Park has affected you (positively or negatively)? If yes, please explain (use additional paper if necessary).

15. Please tell us how much of a threat you believe each of the following is to the health of the Great Barrier Reef:

	No Threat	Minor Threat	Major Threat	Don't Know
a) Marine pollution	1	2	3	4
b) Land-based pollution (run-off)	1	2	3	4
c) Over fishing by recreational fishers	1	2	3	4
d) Over fishing by commercial fishers	1	2	3	4
e) Marine tourism	1	2	3	4
f) Crown of thorns starfish	1	2	3	4
g) Climate change / coral bleaching	1	2	3	4
h) Coastal development	1	2	3	4
i) Aquaculture	1	2	3	4

Great Barrier Reef Marine Park Recreational Fishing Survey — Page 5

16. Please indicate the extent to which you agree or disagree with each of the following statements about management of the Great Barrier Reef Marine Park.:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) The 2004 Zoning Plan will help ensure the survival of the Great Barrier Reef.	1	2	3	4	5
b) The 2004 Zoning Plan will help ensure sustainable fisheries in the Great Barrier Reef.	1	2	3	4	5
c) The 2004 Zoning Plan was necessary to maintain the Great Barrier Reef in a healthy condition.	1	2	3	4	5
d) Protecting the diversity of marine life is the most important goal of managing the Great Barrier Reef	1	2	3	4	5
e) Rezoning the Marine Park was the best option for long-term protection of the Great Barrier Reef.	1	2	3	4	5
f) The 2004 Zoning Plan has reduced the impact of recreational fishing on the Great Barrier Reef.	1	2	3	4	5
g) The 2004 Zoning Plan has reduced the impact of commercial fishing on the Great Barrier Reef.	1	2	3	4	5
h) The 2004 Zoning Plan has reduced the impact of tourism on the Great Barrier Reef	1	2	3	4	5
i) I trust the Great Barrier Reef Marine Park Authority to do what is best for conservation of the Great Barrier Reef.	1	2	3	4	5
j) I trust the Great Barrier Reef Marine Park Authority to consider the concerns of recreational fishers when making decisions about management of the Marine Park.	1	2	3	4	5
k) The Great Barrier Reef Marine Park Authority is doing a good job of managing the Great Barrier Reef.	1	2	3	4	5
l) Compared to other groups (e.g., commercial fishers, tourism), recreational fishers received fair treatment in the 2004 rezoning process.	1	2	3	4	5
m) Recreational fishers were adequately consulted about the 2004 Zoning Plan.	1	2	3	4	5
n) Recreational fishers should have been compensated in some way for areas closed to recreational fishing under the 2004 Zoning Plan.	1	2	3	4	5
o) Zoning of the Great Barrier Reef is adequately enforced.	1	2	3	4	5
p) Information about zoning in the Great Barrier Reef is readily available to recreational fishers.	1	2	3	4	5

17. Are there any locations in the Great Barrier Reef Marine Park where you used to fish regularly but now can't because they were rezoned as Green Zones (i.e., no-take areas) under the 2004 zoning plan?

1 No → Please skip to **Question 21**
2 Yes

<u>How many</u> of your regular fishing locations were turned into Green Zones under the 2004 Zoning Plan?

______ Locations

Approximately <u>what percentage</u> of the area inside the Marine Park that you used to fish regularly was turned into Green Zones under the 2004 Zoning Plan?

1 less than 25%
2 25% to 50%
3 51% to 75%
4 more than 75%
5 don't know

18. Have you compensated for the loss of access to new green zones by fishing at <u>new locations</u> inside the Marine Park that you did not fish prior to the rezoning?

1 No → Please skip to **Question 19**
2 Yes

Overall, how would you rate the quality of these locations compared to the locations you lost through the rezoning?

1 A lot better
2 Slightly better
3 About the same
4 Slightly worse
5 A lot worse

19. Have you compensated for the loss of access to new green zones by spending <u>more time</u> fishing at your <u>other regular fishing locations</u> inside the Marine Park?

1 No → Please skip to **Question 20**
2 Yes

Overall, how would you rate the quality of these locations compared to the locations you lost through the rezoning?

1 A lot better
2 Slightly better
3 About the same
4 Slightly worse
5 A lot worse

20. Have you compensated for the loss of access to new green zones by fishing more at locations <u>outside the Marine Park</u> (including creeks or freshwater)?

1 No → Please skip to **Question 21**
2 Yes

Overall, how would you rate the quality of these locations compared to the locations you lost through the rezoning?

1 A lot better
2 Slightly better
3 About the same
4 Slightly worse
5 A lot worse

21. In the Great Barrier Reef Marine Park, Yellow Zones are used to increase the protection and conservation of certain areas while providing opportunities for reasonable use and enjoyment of the Park. Yellow Zones place restrictions on commercial fishing (no netting, no trawling, limited crabbing), and also restrict both commercial and recreational fishers to using one line and one hook, except when trolling.

In general, do you think Yellow Zones are a:

1 Very good idea
2 Good idea
3 Neither a good nor bad idea
4 Bad idea
5 Very bad idea

22. Over the past 12 months, approximately how much of your fishing activity in the Great Barrier Reef Marine Park
occurred in Yellow Zones?

1 less than 25%
2 25% to 50%
3 51% to 75%
4 more than 75%
5 don't know

23. **Please indicate the extent to which you agree or disagree with each of the following statements about Yellow Zones in the Great Barrier Reef Marine Park**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) Yellow Zones place too many restrictions on recreational fishers	1	2	3	4	5
b) Yellow Zones place too many restrictions on commercial fishers	1	2	3	4	5
c) Yellow Zones will lead to better recreational fishing in the Park	1	2	3	4	5
d) Yellow Zones have reduced the impact of recreational fishing on the Great Barrier Reef	1	2	3	4	5
e) Yellow Zones have reduced the impact of commercial fishing on the Great Barrier Reef	1	2	3	4	5
f) The restrictions on recreational fishing in Yellow Zones are worth it because of the restrictions on commercial fishing in these areas	1	2	3	4	5

24. In Queensland, government agencies responsible for fisheries and marine park management regularly run public consultation programs to inform people about proposed fisheries and marine park management changes, and to obtain public input and feedback about proposed management changes.

Do you believe that government agencies should consult the public (including recreational fishers) about fisheries and marine park management decisions?

1 Yes ⟶ Please skip to **Question 26**
2 No

25. **Please indicate the extent to which you agree or disagree with the following reasons why government agencies *should not* consult the public about fisheries and marine park management decisions**

Agencies should not consult the public about fisheries issues because..

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a)...consulting the public is too expensive	1	2	3	4	5
b)...fisheries and marine park managers know what is best for our natural resources	1	2	3	4	5
c)...the public has little to add to decisions about fisheries and marine park management	1	2	3	4	5
d)...it is not possible to incorporate the views of the public in decisions	1	2	3	4	5
e)...consulting the public delays the implementation of important management changes	1	2	3	4	5
f)... consulting the public allows some interest groups to have too much influence in decisions	1	2	3	4	5

Please skip to Question 27

26. **Please indicate how important you believe each of the elements below is for effective public consultation about fisheries and marine park issues**

How important is it that public consultation programs...

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
a)...give equal opportunity for all citizens to participate	1	2	3	4	5
b)...result in the best outcome for recreational fishers	1	2	3	4	5
c)...result in the best outcome for the marine environment	1	2	3	4	5
d)...result in an outcome that is fair to all affected groups	1	2	3	4	5
e)... allow resource managers to express their opinions to citizens	1	2	3	4	5
f)... allow citizens to express their opinions to resource managers	1	2	3	4	5
g)...give people a genuine opportunity to influence decisions	1	2	3	4	5
h)...improve the relationship between resource managers and citizens	1	2	3	4	5
i)...do not cost the government too much money	1	2	3	4	5
j)...do not require too much time for people to participate	1	2	3	4	5
k)...do not cost people too much money to participate	1	2	3	4	5
l)...favour the group with the most at stake	1	2	3	4	5
m)...allow local concerns to be incorporated into decisions	1	2	3	4	5
n)...involve the public at all stages of planning	1	2	3	4	5
o)...do not delay the implementation of important management changes	1	2	3	4	5
p)...do not allow any one group to have too much influence in decisions	1	2	3	4	5
q)... follow a process that is easily understood by everyone	1	2	3	4	5
r)... give special consideration to the concerns of recreational fishers	1	2	3	4	5

27. Please tell us how useful you think each of the techniques listed below is as a way for people to learn about fisheries and marine park management issues and have input into management decisions affecting recreational fishing.

	Not at all Useful	Moderately Useful	Very Useful	Don't know
a) Public meetings	1	2	3	4
b) Requests for formal written submissions	1	2	3	4
c) Public hearings	1	2	3	4
d) Public information displays (e.g., at boat shows and fishing shows)	1	2	3	4
e) Educational brochures and pamphlets	1	2	3	4
f) Agency branch offices in local communities	1	2	3	4
g) Citizen advisory committees (e.g., Local Marine Advisory Committees - LMACs)	1	2	3	4
h) Surveys	1	2	3	4
i) Interactive web sites for submission of comments	1	2	3	4
j) Toll-free telephone number for submission of comments	1	2	3	4
k) Engagement of recreational fishers in research (e.g., fish tagging programs, recreational fishing logbooks)	1	2	3	4
l) Other (explain) ________	1	2	3	4

28. Did you attend a public meeting or make a submission to the Great Barrier Reef Marine Park Authority concerning the 2004 rezoning of the Great Barrier Reef?

1 No
2 Yes

29. How much do you use each of the following types of maps or mapping tools in the course of your fishing activity?

	No Use	A Little Use	Moderate Use	A Lot of Use
a) Paper maps and / or nautical charts	1	2	3	4
b) Global Positioning System (GPS)	1	2	3	4
c) Chart plotter	1	2	3	4
d) Aerial photographs	1	2	3	4
e) Internet maps (e.g., Google Earth)	1	2	3	4
f) Great Barrier Reef zoning maps	1	2	3	4
g) Geographic Information Systems (GIS)	1	2	3	4
h) Interactive mapping applications (e.g., Coastal Habitat Resources Information System – CHRIS; Deep Blue mapping tool)	1	2	3	4

30. Are you:

1 Male
2 Female

31. What is your approximate annual ***household*** income before taxes?

Under $30,000 $30,000 to $59,000 $60,000 to $89,000 $90,000 to 109,999 $110,000 and above

32. Was this survey completed by the person to whom it was addressed?

1 Yes
2 No

Is there anything else you would like to share with us? (use additional paper if necessary)

Would you like a summary of the results of this survey?

Yes   No

Your contribution of time to this study is greatly appreciated. Please return your completed questionnaire in the postage-paid return envelope as soon as possible. Thank you.

Queensland Recreational Fishing Survey
Reply Paid 109
James Cook University
Townsville, QLD 4811

05/07

Summary tables of Spatial Changes in Recreational Fishing Effort and Distribution

Summary of the features, number of fishers and fishing locations, and distance from the nearest boat ramp for major fishing locations in Townsville.

	Feature	Number Fishers	Number Fishing Locations	Distance boat ramps (km) *(mean)*	*(median)*	*(SD)*
Previous (pre)	MNP-18-1082	21	31	42.95	44.59	7.55
	MNP-18-1086	15	17	36.92	37.14	3.46
	MNP_19-1097	12	14	40.13	39.46	1.40
	MNP-18-1077 - MNP-18-1079	9	12	34.95	33.49	4.35
Current (post)	Cape Cleveland - Salamander Reef	28	43	21.03	23.73	6.11
	Bay Rock Reef - Burdekin Reef	24	31	18.2	18.38	1.40
	Rattlesnake Reef - Herald Reef	18	24	25.29	34.78	2.46
	Britomart Reef	11	11	50.35	49.25	5.36
New	Salamander Reef - Cape Cleveland	2	3	22.56	26.31	7.37
	Great Palm Is.Reef	2	2	34.61	34.61	3.29
	Britomart Reef	2	2	43.72	43.72	11.00
	Morinda Shoals	2	2	52.04	52.04	5.36
	Keeper Reefs	1	2	74.92	74.92	14.29
	Roxburg Reef - Backnumbers Reef	3	5	81.54	80.56	4.58
	Pith Reef	1	1	85.50	85.50	-
Fish More	Salamander Reef - Cape Cleveland	6	6	23.19	23.61	9.00
	between Rattlesnake Is.and Magnetic Is.	5	11	27.41	26.38	7.81
	Hinchinbrook Channel-Haycock Is.	5	5	29.90	21.55	29.21
	Nearshore Reefs	6	8	57.99	56.13	17.16
	(i.e. Taylor Reef, Otther Reef, Bramble Reef)					

Summary of the features, number of fishers and fishing locations, and distance from the cost for major fishing locations in Rockhampton.

	Feature	Number Fishers	Number Fishing Locations	Distance boat ramps (km) *(mean)*	*(median)*	*(SD)*
Previous (pre)	MNP-21-1141	10	20	93.14	87.11	16.19
	MNP-23-1160	11	14	29.28	29.35	2.10
	Square Rocks - Miall Island	30	36	15.27	15.24	0.76
Current	Conical Rocks - Corroborree Island	28	29	18.01	18.14	0.79
	Barren Island	20	22	28.35	29.06	2.93
	Perforated Island - Flat Island	15	20	58.31	58.06	2.74
New	Jonhson Patch - Douglas Shoals	9	9	89.68	89.80	1.40
	Perforated Island - Flat Island	11	10	59.00	58.56	2.66
	Timandra Bank - Hummocky Island	5	5	36.89	38.04	4.16
Fish More	Cape Manifold	4	4	54.66	54.76	0.84
	Jonhson Patch - Douglas Shoals	3	3	90.16	90.21	0.50
	Lisa Jane Shoals	2	2	26.16	26.16	0.71

Fishing intensity index and distance values from departure point of major spatial fishing clusters.

Location	Intensity Index				Distance coast (km)			
	mean	S.E.mean	median	SD	mean	S.E.mean	median	SD
Townsville								
Cape Cleveland - Salamander Reef	21.16	1.26	22	7.77	25.10	0.52	26.11	3.23
Bay Rock - Burdekin Reef	15.15	1.08	14	6.89	19.18	0.48	19.14	3.08
Rattlesnake Is. Reef - Herald Is. Reef	13.96	0.58	15	5.93	36.37	0.44	36.94	4.47
Britomart Reef	13.33	0.35	14	2.81	54.40	0.88	54.13	7.14
Hinchinbrook Channel – Haycock Island	10.36	0.42	11	1.98	27.48	6.41	15.98	30.07
Keeper Reef	7.50	1.25	8.50	3.95	73.89	1.37	74.46	4.34
Lodestone Reef	6.57	1.08	8	2.87	71.22	1.51	73.59	3.99
Rockhampton								
Square Rocks – Miall Island	24.74	0.96	24	11.72	15.30	0.15	15.31	1.80
Conical Rocks – Corroboree Island	22.11	1.11	19	14.87	17.86	0.26	17.56	3.38
Hummocky Island	21.17	0.53	22	6.96	38.00	0.29	37.96	3.88
Barren Island	18.34	0.82	16	11.12	28.90	0.23	28.94	3.18
Johnson Patch – Douglas Shoals	14.10	0.31	12	11.14	87.42	0.26	88.01	9.12
Perforated Island – Flat Island	8.05	0.21	2	9.70	57.09	0.17	56.97	7.99

Displacement index values for Townsville and Rockhampton datasets.

Townsville

Respondents No	Average Current distances (km)	Average Previous distances (km)	Difference distance travelled * Killometre (km)	Percentage (%)
1	34.70	39.18	-4.48	11.44
2	15.41	49.14	-33.73	68.63
3	53.50	28.90	24.60	85.13
4	62.95	30.49	32.46	106.49
5	72.38	54.90	17.49	31.85
6	58.90	50.93	7.98	15.66
7	21.54	26.37	-4.83	18.31
8	73.72	69.82	3.90	5.58
9	29.79	44.14	-14.35	32.52
10	21.75	45.77	-24.02	52.48
11	32.25	47.66	-15.40	32.32
12	48.05	34.02	14.03	41.23
13	34.67	36.73	-2.06	5.61
14	23.19	20.31	2.87	14.13
15	26.10	33.11	-7.01	21.17
16	55.40	56.53	-1.12	1.99
17	45.17	45.33	-0.16	0.36
18	29.73	37.90	-8.17	21.55
19	46.34	54.54	-8.19	15.03
20	41.62	37.24	4.38	11.76
21	35.47	34.73	0.75	2.15
22	39.25	58.00	-18.75	32.32
23	47.28	23.66	23.62	99.86
24	38.14	30.67	7.47	24.37
25	55.67	58.21	-2.54	4.37
26	28.07	45.98	-17.92	38.97
27	40.09	36.23	3.86	10.65
28	49.82	28.63	21.19	74.02
29	27.97	66.17	-38.20	57.73
30	31.29	62.87	-31.58	50.23
31	31.25	40.27	-9.02	22.40
32	37.88	36.19	1.69	4.68
33	30.64	13.41	17.23	128.44
34	51.00	37.03	13.97	37.73
35	22.78	45.83	-23.05	50.29
36	27.66	40.73	-13.07	32.08
37	47.58	27.06	20.52	75.84
38	14.23	28.49	-14.25	50.03
39	32.46	39.47	-7.01	17.75
40	40.26	40.07	0.19	0.48
41	51.07	59.88	-8.80	14.71
42	42.01	64.28	-22.27	34.64
43	86.54	35.17	51.38	146.10
44	56.38	39.17	17.22	43.96
45	27.66	39.46	-11.80	29.90
46	39.54	39.04	0.50	1.27
47	40.51	44.20	-3.68	8.33
48	25.92	19.90	6.02	30.24
49	33.30	44.68	-11.39	25.49
50	21.95	11.56	10.39	89.82

Rockhampton

Respondents No	Average Current distances (km)	Average Previous distances (km)	Difference distance travelled * Killometre (km)	Percentage (%)
1	83.50	109.99	-26.50	-24.09
2	72.49	83.12	-10.63	-12.79
3	72.41	76.38	-3.97	-5.20
4	21.48	28.19	-6.72	-23.83
5	13.90	8.24	5.66	68.63
6	73.20	90.43	-17.23	-19.05
7	71.78	84.54	-12.75	-15.09
8	66.32	86.20	-19.88	-23.06
9	73.99	101.70	-27.71	-27.25
10	34.06	31.28	2.78	8.88
11	44.48	66.87	-22.39	-33.48
12	16.83	30.63	-13.80	-45.06
13	58.77	75.80	-17.03	-22.47
14	22.29	28.24	-5.95	-21.08
15	22.50	32.14	-9.64	-30.00
16	16.43	30.24	-13.81	-45.68
17	10.11	26.66	-16.55	-62.07
18	24.75	25.31	-0.57	-2.24
19	7.34	24.36	-17.02	-69.87
20	46.02	97.95	-51.94	-53.02
21	40.75	28.14	12.61	44.80
22	29.34	27.04	2.31	8.53
23	22.98	21.14	1.84	8.68
24	63.92	29.56	34.36	116.27
25	65.22	86.34	-21.12	-24.46
26	65.43	93.44	-28.01	-29.97
27	44.26	95.12	-50.87	-53.48
28	7.30	18.90	-11.60	-61.36

* Positive (+) and negative (-) values indicate displacement further and closer, respectively, from the departure point on the coast in relation to the previous fishing position.

Size of fishing locations in Km^2 according to fishers (N) support of zoning and level of approval of green zones.

	N	Median	S.E.Mean	SD
Support Zoning				
Good idea	95	47.55	8.27	80.57
Neither	11	75.59	14.61	48.47
Bad idea	17	67.6	26.6	109.68
Level Approval Green Zones				
Number				
Approve	47	48.98	10.29	70.58
Neither	41	38.88	10.31	66.03
Disapprove	35	82.76	18.01	106.53
Size				
Approve	34	40.26	10	58.29
Neither	42	39.78	8.39	54.36
Disapprove	45	78.72	15.86	106.42
Location				
Approve	30	45.55	10.68	58.52
Neither	42	38.59	6.96	45.09
Disapprove	49	82.76	15.23	106.59

Number of current and previous fishing locations in relation to area (Km^2) of the fishing locations.

	N Locations	Valid Percent	Median	S.E.Mean	SD
	0	40.65			
	1	24.39	37.98	27.13	148.61
	2	14.63	98.93	28.67	121.65
	3	6.5	71.35	43.72	123.66
Previous	4	8.13	118.52	48.54	153.48
	5	0.81	68.85		
	6	3.25	59.28	50.16	100.31
	7	0.81	136.84		
	9	0.81	57.01		
	0				
	1	4.1	70.6	27.2	60.81
	2	10.66	152.83	26.45	95.36
	3	12.3	48.97	31.85	123.35
	4	18.03	31.05	16.55	77.63
	5	18.85	40.01	9.45	45.33
	6	12.3	85.98	29.36	113.7
Current	7	4.92	52.53	21.92	53.68
	8	7.38	31.91	21.14	63.42
	9	3.28	33.53	11.99	23.99
	10	0.82	20.6		
	11	3.28	45.32	27.61	55.22
	12	1.64	40.93	22.22	31.42
	13	0.82	273.88		
	14	0.82	41.57		
	19	0.82	82.99		

Number of current fishing locations in relation to area (Km^2) of the fishing locations in Rockhampton.

N Locations	Valid Percent	Median	S.E.Mean	SD
1	1.85	173.6		
2	20.87	158.57	27.58	91.48
3	9.26	100.59	25.84	57.79
4	25.93	27.47	4.99	18.68
5	20.37	40.01	5.89	19.53
6	7.41	35.11	13.72	27.45
7	9.26	51.85	7.25	16.22
8	3.7	29.78	2.13	3.01
10	1.85	20.6		

Summary tables of Social Assessment of Fishers' Perceptions of Public Participation Process and Consultation techniques'

Participants (P, n= 322) and non-participants (NP, n= 444) believes with statements about the trust in the management agency and the consultation process of the GBRMP.

	Level of Agreement (% respondents)					
Trusting of the GBRMPA and the consultation process [(a)]	Disagree		Neutral		Agree	
	P /	NP	P /	NP	P /	NP
I trust the Great Barrier Reef Marine Park Authority to do what is best for conservation of the Great Barrier Reef [(b)]	49/	25	24/	23	27/	52
I trust the Great Barrier Reef Marine Park Authority to consider the concerns of recreational fishers when making decisions about management of the Marine Park [(b)]	60/	33	15/	19	25/	48
The Great Barrier Marine Park Authority is doing a good job of managing the Great Barrier Reef [(b)]	44/	21	31/	35	25/	44
Compared to other groups (e.g. commercial fishers, tourism), recreational fishers received fair treatment in the 2004 rezoning process [(b)]	58/	29	20/	34	22/	37
Recreational fishers were adequately consulted about the 2004 Zoning Plan [(b)]	57/	35	18/	38	25/	27
Zoning of the Great Barrier Reef is adequately enforced	31/	26	23/	35	46/	39
Information about zoning in the Great Barrier Reef is readily available to recreational fishing	11/	7	9/	16	80/	77

[(a)] Cronbcha's α =0.79 indicates an acceptable level of internal consistency reliability. Measured on a 5-point scale with response ranging from (1) Strongly disagree to Strongly agree.
[(b)] Indicates a significant difference in distribution of responses between groups $p \leq 0.001$ for all).

Participants (P, n=320) and non-participants (NP, n=444) level of importance with statements about elements of public consultation programs.

Elements of consultation programs [a]	Level of Importance (% of respondents)					
	Low		Moderate		High	
	P /	NP	P /	NP	P /	NP
Give equal opportunity for all citizens to participate [b]	2/	1	21/	33	77/	66
Result in the best outcome for recreational fishers [b]	4/	2	32/	41	64/	57
Result in the best outcome for the marine environment	1/	1	15/	15	84/	84
Result in an outcome that is fair to all affected groups [b]	1/	1	20/	28	79/	71
Allow resource managers to express their opinions to citizens [b]	2/	2	30/	33	68/	65
Allow citizens to express their opinions to resource managers	0/	2	18/	29	81/	70
Give people a genuine opportunity to influence decisions [b]	1/	1	17/	29	82/	70
Improve the relationship between resource managers and citizens [b]	3/	3	19/	26	78/	71
Do not cost the government too much money	27/	19	49/	53	24/	28
Do not require too much time for people to participate	11/	11	55/	57	34/	32
Do not cost people too much money to participate	9/	6	39/	37	52/	57
Favour the group with the most at stake	34/	31	41/	51	25/	18
Allow local concerns to be incorporated into decisions [b]	2/	2	15/	30	83/	68
Involve the public at all stages of planning [b]	1/	2	19/	33	80/	65
Do not delay the implementation of important management changes	8/	7	38/	38	54/	55
Do not allow any one group to have too much influence in decisions	3/	1	14/	18	83/	81
Follow a process that is easily understood by everyone	1/	1	11/	12	88/	87
Give special consideration to the concerns of recreational fishers [b]	7/	7	34/	44	59/	49

[a] Cronbcha's α =0.87 indicates an acceptable level of internal consistency reliability. Measured on a 5-point scale with response ranging from (1) not all important to extremely important.
[b] Indicates a significant difference in distribution of responses between groups ($p \leq 0.01$ for all).

Recreational fishers level of agreement with statements about reasons why government agencies should not consult the public about fisheries-related issues. (Only respondents who answered negatively to the question about whether the public should be consulted were asked this question (n=22).

Reason why the public should not be consulted	Level of Agreement (% of respondents) Disagree	Neutral	Agree
Consulting the public is too expensive	33	38	29
Fisheries and marine park managers know what is best for our natural resources	14	19	67
The public has little to add to decisions about fisheries and marine park management	19	38	43
It is not possible to incorporate the views of the public in decisions	43	38	19
Consulting the public delays the implementation of important management changes	5	29	66
Consulting the public allows some interest groups to have too much influence in decisions	5	10	85

Participants (P, n=320) and non-participants (NP, n=446) perceptions about the usefulness of various techniques for consulting the public and educating them about fisheries and marine park management issues.

Technique [a]	Perceived Usefulness (% of respondents) Low P / NP	Moderate P / NP	High P / NP
Public meetings [b]	3/ 6	33/ 48	64/ 46
Requests for formal written submissions [b]	11/ 13	46/ 55	43/ 32
Public hearings [b]	3/ 9	36/ 40	61/ 51
Public information displays (e.g., at boat shows and fishing shows)	3/ 1	14/ 15	83/ 84
Educational brochures and pamphlets	3/ 1	22/ 21	75/ 78
Agency branch offices in local communities	14/ 8	34/ 41	52/ 51
Citizen advisory committees (e.g., Local Marine Advisory Committees – LMACs)	12/ 9	42/ 50	46/ 41
Surveys	9/ 5	35/ 48	56/ 47
Interactive web sites for submission of comments	8/ 4	36/ 40	56/ 56
Toll-free telephone number for submission of comments	10/ 8	37/ 42	53/ 50
Engagement of recreational fishers in research (e.g., fish tagging programs, recreational fishing logbooks)	7/ 7	28/ 31	65/ 62

[a] Cronbcha's α =0.74 indicates an acceptable level of internal consistency reliability. Measured on a 4-point scale with response: (1) not all usefull, (2) moderately useful, (3) very usefull, (4) don't know.
[b] Indicates a significant difference in distribution of responses between groups (p=0.00 for all).

Participants (P, n=364) and non-participants (NP, n=461) level of use of maps and spatial – related tools.

Tool [(a)]	Level of Use (% respondents)					
	No Use		Moderate		High	
	P /	NP	P /	NP	P /	NP
Paper maps/or nautical charts[(b)]	6/	21	60/	58	34/	21
Global Positioning System (GPS)[(b)]	11/	30	24/	28	65/	42
Chart Plotter[(b)]	35/	58	24/	19	41/	22
Aerial photographs	67/	75	30/	21	3/	4
Internet maps (i.e. Google earth)	58/	65	36/	61	6/	4
GBR zoning maps[(b)]	2/	12	50/	54	48/	34
Geographic Information Systems (GIS)	83/	87	15/	11	2/	3
Interactive mapping applications (i.e. Coastal Habitat Resources Information Systems – CHRIS, GBRMPA GIS Zoning maps Deep Blue mapping tool)	87/	86	11/	13	2/	1

[(a)] Cronbcha's α =0.65 indicates an acceptable level of reliability.

[(b)] Indicates a significant difference in distribution of responses between groups (p=0.00 for all).

Content analysis of open-ended comments related to fishers' (participants=P, non-participants= NP) motivation, consultation, and value of participation in fisheries-marine park issues.

Motivations to participate and reasons to not participate in consultation programs.

Code (coverage %)*	Comment
	Motivations to **participate** in fisheries- or marine park-related issue
be informed (59.23%)	• as a user of the area I should be informed on what is happening. • I wanted to see what it is all about. To educate ourselves. • it was all new to us and we needed to know what was going to happen.
attachment to fishing (43.35%)	• I have been fishing for most o my life and was interested. • I fish and I'm a stakeholder. I have concerns for my children who enjoy fishing. • it was my livelihood at that time and I wanted to have a say how it will go.
influence decisions (36.86%)	• I wanted to keep my fishing spots. I have been in the fishing/tackle industry for 10 years and wanted to keep the industry intact. • I am a passionate recreational fisher and I wanted to see the zoning have the greatest effect. I also didn't want to see specific spots locked up. They need to leave us some spots.
give input (26.54%)	• I'm a fisherman. I had my concerns and needed to have my say. • I prepared a submission on behalf of an interested group of residents and fishers. • to have my say about areas where I fish.
	Reasons NOT participate in fisheries- or marine park-related issue
distrust (63.29%)	• I don't believe that any of our concerns were at all considered. • no because they increased the zoning from 3-33% changed it from what they said they would do. No trust now. • our input felt on deaf ears. Their agenda was set in stone before they consulted us.
no individual impact (27.28%)	• it was impossible to have an impact individually. It is time consuming to raise the support to make ever a small change in. • feel that the answers were written before the questions were asked. It was driven by agencies no matter what I said it didn't make a difference.
more flexible agency (23.80%)	• we didn't get anywhere. They just zoned what they wanted to zone. • I suggested alternatives like the 'fragmented zoning' as nurseries but they ignored it. • they went ahead and did what they wanted to do.
inadequate consultation process (23.09%)	• the way they ran it, it was a waste of time, they didn't listen. Today's interview was the only person that has asked questions about how I feel about fishing. Should have been positive participation. • to a lesser degree, too much beaurocracy. • never become involved because of 'work commitments'. "I am usually working when the meetings are held. Feel that it falls on deaf areas".

* Coverage refers to the percentage of the source that is coded at the node (i.e. concerns, motivations to participate, reasons to not participate). The qualitative analysis software QSR NVivo V.7.0.247.0 SP2 was used for the content analysis.

Reasons for resource management agencies **consult or not consult the public.**

Code (coverage %)*	Group	Comment
Reasons for resource management agencies **consult or not consult the public**		
right to be informed/consulted (79.43%)	P	• we are stakeholders and have a right to know what is happening. • as fishers we have a right to be consulted in management issues. • we are stakeholders and as such should have a say and be kept informed about what is happening. I am out there (ocean) and see first hand the issues that affect fishing.
	NP	• don't think government should be swayed by public opinion. Should do what is best to protect the environment. Public are emotive, are ill equipped to make decisions. Public can be informed about the reasons why things are done. There are things that have to be done for the greater good.
better/proper consultation (38.70%)	P	• to educate people about the issues. The reason most people are upset about things is because they don't' have information, it hasn't been explained properly. • the departments need to be more present and work more with the fishing community to source who is doing the wrong things. • consultation process is only lip service at this time., more interest in the bureaucracy than the resource.
	NP	• it effects a lot o people lives. There are lot of recreational fishers and they should have a say. The agencies should get more information out.
representativeness (local knowledge) (24.34%)	P	• absolutely, can't people making decisions without asking the public. Get a broad overview of many types of fishers and non-fishers. This will give a more balanced decision. • the local fishers have local knowledge which would compliment the agencies knowledge.
transparency (17.07%)	P	• they need to do more than consult. Some of the agencies have the attitude that they make the rules and then ask us how much we don't like it and then say that is how it is. • all Australians are shareholders in the reef. Any issues affecting the reef should be discussed and debated with the public.
	NP	• I have a web to record our concerns. So everyone has a view, far the silent majority. Everyone has access to the web. It is an easy medium to use. But everyone needs to know it is there and where it is.
economic issues (16.24%)	P	• recreational fishing is a expensive hobby that provides money for local communities and government departments therefore the public should be consulted. • yes, as we are the users of the area and spend a lot of money.
	NP	• yes, it's good that they are doing something, making decisions. However the changes mean travelling further and getting less fish so we should be able to discuss this.
experts (7.98%)	NP	• they shouldn't consult, they are the experts and some fishers just get hot under the collar and do not have a positive injection • no, the public have unqualified opinions and get emotional about what they are saying. • don't think government should be swayed by public opinion. Should do what is best to protect the environment. Public are emotive, are ill equipped to make decisions. Public can be informed about the reasons why things are done. There are things that have to be done for the greater good.

* Coverage refers to the percentage of the source that is coded at the node (i.e. concerns, motivations to participate, reasons to not participate). The qualitative analysis software QSR NVivo V.7.0.247.0 SP2 was used for the content analysis.

Perceptions of value of participation.

Code (coverage %)*	Comment
	Do you feel your **participation** was **worthwhile?**
distrust/pre-determined decisions (61.84%)	• no, I feel that the new zones and laws were already in place when the meeting was happening. • no, I feel that the decisions were already made before consultation with us. • no, I believe the zones were already in place before the meeting.
inadequate consultation process (19.72%)	• not really, the meeting I attended turned into people arguing. • yes, we tried to do something. We had a go. I feel angry that we got shafted. I want more information and truth next time. • no, the meeting I attended was pathetic, no control over it and they would not listen to us
influence decisions (16.92%)	• it's always worthwhile having a say, participating. Trying to get my point across. • I think so. I had my say but not much happened. Less would have happened if we all sat back and did nothing. • reasonably. We eventually got then to make a few changes.
be informed/no complaint (5%)	• yes, worthwhile on a personal level, more informed. • yes, for educating myself.

* Coverage refers to the percentage of the source that is coded at the node (i.e. concerns, motivations to participate, reasons to not participate). The qualitative analysis software QSR NVivo V.7.0.247.0 SP2 was used for the content analysis.

Necessary changes in the 2004 zoning plan.

Code (coverage %)*	Comment
	Are there any **aspects of the zoning plan** that you would like to see changed?
re-assessment (45.43%)	• we weren't hit too hard here but the blokes up north were - they should re-assess there. • yes, remove the beach yellow zones. • reconsider where some are and maybe open them for a year and then close them again. • review the green zones close to land/island coastlines. • zoning should be fragmented, not blocked. keep the % the same but fragmented, no need for such large blocks. • re-shape the green zones, so they are easier to navigate, and open them after 5 years.
rotation zones (24.57%)	• rotation of no take zones. • rotating the green zones and more consideration into how far the recreational fisher has to travel. • alternate the zones: e.g. change blue to yellow, yellow to green etc. • they should open them up after 5 years. Alternate opening and closing the reefs, including reefs that have not been zoned as they are being overfished.
follow-up science (10.37%)	• should have more science research done. • definitely needs to be reviewed. Get some science data. It was supposed to be zoned for habitat protection, lest get the science data out there for everyone to see. • not sure they used scientific information to place them where they did.

* Coverage refers to the percentage of the source that is coded at the node (i.e. concerns, motivations to participate, reasons to not participate). The qualitative analysis software QSR NVivo V.7.0.247.0 SP2 was used for the content analysis.

Appendix D

Chapter 6 supporting information (key informant interview protocol and list of detailed management issues identified by the participants of the workshop)

Key informant interview protocol

Date:_______________ Id:_______________

1. Introduction (5 MINUTES)

a. Thank you for coming / agreeing to be involved in the research:
b. Introduce project context, objectives and methodology; and researcher/s:

Hi, my name is Débora De Freitas, and I'm enrolled as a PhD student at the James Cook University in Townsville. I'm conducting a study on how geographic information and new geospatial technologies can be used as a tool to facilitate coastal management, both in terms of stakeholder participation and to assist in integrating science into management.

Main topics about the adaptive deployment of sensor networks in the coastal zone of the Great Barrier Reef coastal zone were identified during one-day workshops hold on the 5th December 2006 and 26th of July 2007, on 'The Adoption of Sensor Networks by Coastal Managers'. Today, I'm interested in hearing your opinion on more specific points related to the deployment of sensor networks technology and the delivery of real-time spatial data by research.

The interview that you previously agreed on participate takes about 30 to 45 minutes of your time to complete.

c. Ask participants to introduce themselves:
how long they work is that position, etc…

d. Seek permission to tape session; clarify that tape is intended as a back-up for researcher only (interview procedures):

This interview will only be used for my own university study. All information provided will remain confidential and anonymous unless prior consent is sought.

To assist me in writing up an accurate summary of our conversation, I would like to tape the interview. If you don't want me to keep a record on any point – I won't. Do you permit me to do this?
[provide Informant consent form]

If at the end of the interview you feel you would like to have a copy of my interview notes, I'd be happy to provide them.

Do you have any questions? Is it OK to proceed on this basis?

d. General introductory questions [open/broad questions about participant's activities]:

To begin with, could you tell me about your responsibilities on marine and/or coastal management?

Do you have any links with water quality monitoring programs and/or public participation process?

1. Yes. If yes please explain:
2. No. skip to questions.

Section A: General Principles (15 MINUTES)

Brief interviewee with summary of main outputs of the workshops: Main topics identified by the participants about the adaptive deployment of sensor networks in the GBR coastal zone:

• measurable variables x desirable variables
• effect of real-time data access on management thinking and responses
• building expectations in both managers and public
• information overload, interpretability & accessibility
• bi-directional communication
• temporal-spatial scale (e.g. amplitude, spatial disposition, sampling frequency, adaptive sampling scheme)
• field deployment problems: technical (e.g. loss of instruments), environmental (e.g. topography), socio-cultural (e.g. vandalism)
• adaptive sampling scheme
• sensor networks as a science-driven initiative

A.1. In general, what you think about this initiative on adaptive deployment of new spatial technologies such as the sensor networks?

1. very good idea
2. good idea
3. bad idea
4. very bad idea
5. neither a good nor bad idea

Why?

A.2. What is in your opinion about the main issues between scientists and policy makers in technology and knowledge transferring?
[prompt: suggest a way that scientists and policy makers work more efficiently together in environment]

A.3. For your situation, what is the current process of knowledge and technology transference between science and management?
[prompt: discuss how scientists can be successful in bringing their knowledge and new technology to develop applications for environmental policies]

A.4. Overall, are the scientific findings useful in the decision process? [prompt: context]

1. YES, Explain.

2. NO, Why not?

A.5. During the workshop information overload was addressed as an important issue for environmental decision makers and researchers.

a. Is information overloading a problem for you?

1. YES. How serious is this problem for the development of your activities?

2. NO

b. What, in your opinion, are the effects of information overload of real-time data on coastal management thinking and responses?

A.6. It was stated during the Workshop you participated in December last year that fast sampling rates which are easily accessible can build high expectations in both environmental/coastal managers and public. Do you agree or disagree with that? Why?
[prompt: managers present in the workshop said community would increase pressure on managers to give faster decisions, it means, public pressure would increase]

There is a well-documented need to improve the flow of information in both directions between scientists and decision-makers to improve relationship and to build trust in the science-policy process. Improved access to scientific information and to the hands-on experience of decision-makers has multiple benefits from the perspective of developing new management options and adaptive capacity.

However, decision-makers and scientists rarely develop the types of relationships and information flows necessary for full integration of scientific knowledge into the decision-making process.

A.7. Please indicate the extent to which you agree or disagree with each of the following statements on science-policy interface:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. scientists identify critical issues based on understanding of the nature of the environment management, while environmental/coastal managers based on experience on particular system ………………………………	1	2	3	4	5
b. while environmental/coastal managers' timeframe is immediate (operations) and long-term (infrastructure); and scientists' timeframe is variable …………………	1	2	3	4	5
c. science goals are defined by prediction explanation and understating of natural Systems; and management goals are determined by optimization of multiple conditions and minimization of risk…….	1	2	3	4	5
d. scientists assume that environmental/coastal managers do not articulate their needs effectively and often do not know what they want………………………	1	2	3	4	5
e. environmental/coastal managers assume that scientists do not communicate effectively to non-scientists……………,……………………..	1	2	3	4	5
f. science's main challenge is to share scientific data in understandable terms and on responding to emergent policy needs………………………………	1	2	3	4	5
g. policy's main challenge is the early engagement of scientists and policy-makers from the initial framing of management priorities…………………..	1	2	3	4	5
h. other (explain):_______________…..	1	2	3	4	5

Section B: Management issues relevant to Sensor Networks (15 MINUTES)

Brief interviewee with summary of main outputs of the workshops:

- climate change
- coral bleaching
- long-term changes in ocean temperature
- biological census data
- hydrodynamic models of reef circulation
- sediment & nutrient solution
- real-time information from high risk areas (e.g. ports, shipping channels)
- compliance enforcement at high risk areas (preservation zones)
- wildlife studies (e.g. influence of changes sea surface temperature and seabird feeding, beach sand temperature

Scientific data provided by new technologies often does not fit the needs or interests of environmental managers and decision makers or they are not presented in a way that can be used in a management framework.

B.1. What is your opinion about the potential for improving provision of real time data for decision making?

B.2. How will fine-grained observations of the environment provided by sensor networks change your daily policy-management or research decisions?

B.3. What decisions will you be able to do in the future following the implementation of sensor networks and geospatial technologies that you can't do today? How are you planning to implement such decisions?

B.4. How current do you need the real-time data to be to assist your operations?

a. This list shows the current, potential and planned data to be provided by the sensor networks. Could you please tell me if they are of low, medium, or high priority to your management?

state	Variables	Priority		
		Low	Medium	High
Current/core	Temperature pH Depth pressure			
Planned	Light at depth video			
Potential/designed	PAR at depth UV at depth $C0_2$ PAM fluorometry Turbidity Nutrients			

B. 5. Earlier during the workshop, participants addressed the main management issues relevant to sensor networks. Can you please indicate how relevant are the following topics to your management decision-making context, on a scale of 1 to 3 (where 1= not relevant; and 3 = relevant)?

VARIABLE	Not Relevant	Moderately Relevant	Relevant
a. climate change ……..……………….....	1	2	3
b. coral bleaching ……..……………….....	1	2	3
c. long-term changes in ocean temperature……………….....	1	2	3
d. biological census data..………….….....	1	2	3
e. ground truth hydrodynamic models of reef circulation……….….....	1	2	3
f. sediment & nutrient management (e.g. map flood plumes, monitor catchment runoff)…..………………....	1	2	3
g. real-time information from high risk areas (e.g. oil or chemical spills around major ports and shipping channels) ………………....	1	2	3
h. compliance enforcement at high risk areas (preservation zones)..	1	2	3
i. wildlife studies (e.g. influence of changes sea surface temperature and seabird feeding, beach sand temperature and turtle nesting, marine mammals' songs and population estimates)…………………...	1	2	3
j. information and educational resource (e.g. live video camera at reefs link through the web) ……....	1	2	3
k. other (explain)____________ …….....	1	2	3

If 1 or 2, why?

B.6. In its first implementation stage, the Sensor Networks project is planning to deploy sensors at the following locations:

Spatial coverage		
Site	SCIENCE Current and projected sites to deployment of sensors [AIMS weather stations]	MANAGEMENT GBRMPA temperature loggers are/will be deployed in GBR [Island research stations (Tropical Marine Network): Lizard, Orpheus, Heron, One Tree]
Nelly Bay (current pilot)	×	
Davies Reef	×	
Lizard Island research station	×	×
Heron Island research station	×	×
Orpheus Research station (Island)	×	×
Morton Bay	×	
One Tree island	×	×
Myrmidon Reef	×	
Snapper Island North		×
Snapper Island South		×
Pandora Reef		×
Fitzroy Island West		×
Fitzroy Island East		×
High Island West		×
High Island East		×
Frankland Group West		×
Frankland Group East		×
North Barnard Group		×
King Reef		×
Dunk Island North		×
Dunk Island South		×
Havannah Island		
Middle Reef		
Geoffrey Bay		
Double Cone Island		
Daydream Island		
Shute & Tancred Island		
Pine Island		
Hook Island		
Dent Island		
Seaforth Island		
Peak Island		
Barren Island		
Pelican Island		
Humpy & Halfway Island		
Middle Island		
North Keppel Island		

a. How relevant are those places within the scope of your activities?

b. Are there other priority places you would like to be included in the sensors networking? If yes, which ones?
[prompt: table for my understanding]

Section C: Organisational and Technical modifications (10 MINUTES)

Brief interviewee with summary of main outputs of the workshops:

- measurement of non-normal parameters
- ground truth
- real-time measurement develop of response
- technical-infrastructure & operational skills requirements
- intellectual property rights
- cost and reliability
- fine temporal measurements
- accurate meta-data
- efficient power usage and high bandwidth data transmission

Collecting real-time data at the right spatial and temporal scale of is an important factor to understanding dynamic marine and coastal processes.

C.1. Within the scope of your activities which are the main constraints to the adoption of real-time spatial data?
[prompt: organisational readiness, budgetary limitations, complexity of technology, lack of experienced technical staff, lack of interest among the public, infrastructure and accessibility problems, privacy and data related problems, lack of understanding the planning system, lack of vision at your institution, restrictions of the planning legislations]

C.2. What are the benefits for the adoption of such technology and data?
[prompt: of adopting online systems: information sharing, community feedback, application lodgment, online decision and plan making, online polling, perceived benefits of the technology]

a. And how about the costs involved?

C.3. Do you agree (A) or disagree (D) that information licensing arrangements and standardized terms, actions and rules for information transactions:

1. facilitate improved access to, and use of, government held data and information (   )
2. establish a standard, single interface for other jurisdictions and the private sector(   )
3. preserve the government's Intellectual Property (   )
4. reduce legal risks associated with misuse of data and information products (   )
and services

C.4. Tell me what you think are the real and perceived institutional barriers and incentives that may influence the adoption and use of real-time geospatial data and technology?

a. Any suggestions of how to overcome those barriers?

C.5. Do you think information for management must be driven by management needs or by science?

Why?

C.6. And how about initiatives such as the Sensor Networks which is trying to adopt an adaptive and collaborative approach integrating science and management from the development and deployment phases of technology's implementation process?

Section D: Information and communication channels (10 MINUTES)

Brief interviewee with summary of main outputs of the workshops: Earlier at the Workshop participants have identified that international court proceeding, online graphic data and data stream, real time video of remote locations as educational tool, 3D visualization programs, scaleable visualization, and reports, alerts (e-mails, SMS) are (or should be) the main information and communication channels used between management and science.

D.1. Are there information and communication channels/tools that have been used to support engagement and to provide data products (feedback) to stakeholders?

1. Yes. If yes, could you please specify?
[prompt: e.g. public meetings, written consultation/surveys, indirect communication toll free telephone number, put information available on website (newsletters, fact sheets, brochures, reports and plans, online forum,), mailing lists, chat rooms, other?]

2. No

D.2. Is a bidirectional data flow required between managers and researchers?

1. Yes. If yes, how it should work?
[prompt: studies/monitoring programs may require periodic access and exchange of data resources available over the internet?]

2. No. If no, why not?

Most coastal data and government decisions are spatial, so applying spatial information and technologies such as sensor networks to coastal issues supports many management tasks, including access to long-term autonomous real-time information, quality control over data captured, and enhanced decision-making. The linkage between real-time environmental visualization, GIS and web-based tool has been increasingly used to fill this gap between data provision and delivery enhancing information sharing and even supporting new methods for participation. However, such online availability of collected data pose technical and legal challenges, including: user interface, functionality, network connection, hardware and software costs, data ownership, copyright and intellectual property rights.

D.3. Do you see a potential of new technologies such as sensor networks and GIS strengthen participation between environmental/coastal managers and researchers? If so, how?

D.4. Compared to other information and commutation mechanisms we talked about before, what do you think is the current and future role of innovative geovisualization (e.g. Google Earth) tools such as Web-based reporting and interactive mapping tools?

D.5. Do you think GBR sensors' data collected should be:

a. public available?

b. available using a web interface?

Section E: Public participation process (10 MINUTES)

Public participation has been recognized as an important component on the interface between *science, policy and society. Effective public participation in decision-making is a key element of developing effective environmental planning and management strategies.*

E.1. In a few sentences, how would you define public participation? Who is the public and what is meant by participation in the management process of coast and marine-related issues in the Great Barrier Reef Marine Park?

E.2. Do you believe that government agencies should consult the public about marine and coastal-related management decisions?

1. Yes. If yes, please indicate the reasons why.

2. No. If no, please indicate the reasons why.

E.3. Please indicate the extent to which you agree or disagree with each of the following statements about public participation process:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. public participation policies need to be been fully incorporated into decision making processes ……………………………… …...	1	2	3	4	5
b. public participation is recognized as a major component of the agency's core aims …………....	1	2	3	4	5
c. appropriate structures and mechanisms are established to provide avenues for public participation in decision making…………………… ..	1	2	3	4	5
d. adequate staffing and resources are provided to manage an effective public engagement program…………………………………………......	1	2	3	4	5
e. avenues are available for participation in related activities such as interpretation, education, research and monitoring……………....	1	2	3	4	5
f. involving the public allows some interest groups to have too much influence in decisions……………………………………………....	1	2	3	4	5
g. public participation is not important because marine and coastal managers know what is best our natural resources………………....	1	2	3	4	5
h. public participation process is time consuming and expensive……………………………....	1	2	3	4	5
i. involving the public delays the implementation of important management changes……………………………………………...	1	2	3	4	5

Section F: Researcher follow-up notes

F.1. How the interview went? (was the interviewee talkative, cooperative, nervous, etc…)

F.2. Where the interview took place?

F.3. Any other feelings about the interview? (did it open up new avenues of interest?)

Section G: Follow-up questions

Do you mind telling me a few demographic details?

M / F Age group:

type of education / training:

Have you got any other comments?

Would you like a summary of the results of this research?

1. Yes
2. No

Your contribution of time to this study is greatly appreciated and your thoughtful and meaningful input will certainly help the application of data provided by the sensor networks with a more management-driven perspective.

Your support will contribute to the development of a Science-Policy process report and also the publication of peer-review paper such as ‘Networking Science and Management in the context of the Great Barrier Reef Coast, Australia’ (current under development).

Detailed description of the management issues identified by the participants of the sensor network workshop.

1. Understanding system components and interactions

Measurement of water (marine) quality at biological monitoring sites		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Lack of long-term funding to support network (L)	projected	regional
Recognition of advantage of network (R)	current	regional
Large geographic region to monitor (R)(L)	current	regional
Data storage infrastructure not yet developed (L)	current	local
Technical		
Key parameters do nor have sensors get (L)	current	local
Long distance for transmission data by radio (L)	current	regional
Damager/vandalism of deployed equipment at water surface (L)	current	local
Rigorous quality assurance/quality control on collected data (R)	current	regional

Turbidity and PAR long term data		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Ability to determine long term trends (R)	projected	national
Technical		
Agreement on methods (R)	current	national
Agreement on quality assurance requirements (R)	current	national

Measurement of water circulation patterns		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Large geographic region to monitor (R)(L)	current	regional
Technical		
Rigorous quality assurance/quality control on collected data (R)	current	regional

Measurement of flood plume water quality		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Key parameters do nor have sensors get (L)	current	local & regional
Long distance for transmission data by radio (L)	current	regional
Damager/vandalism of deployed equipment at water surface (L)	current	local
Rigorous quality assurance/quality control on collected data (R)	current	regional

Optimal management/protection		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Better conceptual and numerical models for reef and rivers (R)	projected	local

Measurement of catchment water quality indicators to marine environment		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Key parameters do not have sensors yet (L)	current	local

Linking water quality with ecological outcomes		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Better conceptual + numerical models for reef + rivers (R)	current	regional
Lack of casual – effect models (L)	current	regional

Chlorophyll a long term data		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Agreement on methods (R)	current	national
Agreement on quality assurance requirements (R)	current	national

2. Confidence in measuring water quality (relationship between parameters & water quality)

Water quality		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Reliability (R)	current	local & regional
Accuracy (R)	current	regional
Linkable to management parameter (R)	immediate	local & regional
Maintenance requirement/cost & frequency (R)	current	local & regional

Standards for metadata		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Organisational/Institutional		
Endorse Standard (R)	immediate	global
Technical		
Design (R)	projected	global
Decide on standard (R)	immediate	global
Implementation of standard (R)	future	global

Standards for provision of data to network (QA/QC)		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Organisational/Institutional		
Endorse Standard (R)	projected	regional
Technical		
Decide on standard (R)	projected	regional
Implementation of standard (R)	future	regional

Consolidation of regional data		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Organisational/Institutional		
Lack of integration a cross skills/institutions (L)	current	local & regional
Technical		
Data standards (L)	current	national
Trial of data consolidation across themes and institutions (R)	current	local

Kn of system (identifying and characterizing driving relationships - dynamics)		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Organisational/Institutional		
Engagement of user groups in development (R)	current - ongoing	local & national
Development of policy and decision making frameworks that use sensor networks (R)	current	regional
Technical		
Cost (low-costs to make uptake easier) (L)	current - future	local & global

Fate of water quality parameters (temporal/spatial)		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Reliability (R)	immediate	regional
Accuracy (R)	immediate	regional
Linkable to management parameter (R)	immediate	local & regional
Maintenance requirement/cost & frequency (R)(L)	immediate	regional

Models predict coastal water quality (catchment model calibration)		
(R)equirement or (L)imitation	**Temporal scale**	**Spatial scale**
Technical		
Reliability (R)	current	local & regional
Accuracy (R)	current	local & regional
Cheap sensor (R)(L)	projected	regional
Maintenance requirement/cost & frequency (R)(L)	current	local & regional
Agreement on model platform (R)	projected	national

3. Managing the risk of decision making based on sensor data (quality & validation)

Multiple use management strategy and evaluation		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Confidence in data (R)(L)	projected	local
Accuracy of data (R)	future	global
Technical		
Security at RF chip. (L)	current	local
100% public delivery (R)	projected	regional
Vandal safe (R)	current	local

Event detection		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Confidence in data (R)	future	local
Accuracy of data (R)	future	global
Technical		
100% public delivery (R)	projected	local
Vandal safe (R)	current	local

Compliance and enforcement		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Confidence in data (R)	future	global
Accuracy of data (L)	future	global
Technical		
Security at RF chip (R)(L)	current	local
100% public delivery (R)(L)	projected	regional
Vandal safe (R)	current	local

Permits for deployment		
(R)equirement or (L)imitation	Temporal scale	Spatial scale
Organisational/Institutional		
Process for Approval (R)	immediate	regional
Endorse standard (R)	current	regional
Technical		
Design (R)	immediate	regional
Decide on standard (R)	current	regional