Employing informal learning theory and network analysis to improve the way we communicate scientific information to fisheries stakeholders

A thesis

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Abstract

As the understanding of fisheries systems has evolved, so too has the way their management is approached. Traditional, top-down, highly centralised fisheries management is being phased out in favour of models that require the engagement of a wider range of stakeholders. Correspondingly, the ability to communicate effectively and efficiently to stakeholders with a diversity of scientific and experiential backgrounds is becoming a greater priority. This thesis applies informal learning theory to the communication of scientific information to fisheries stakeholders. In the literature review chapters, I identify the failings of old communication models, and discuss how existing theoretical constructs could inform explorations into improving the effectiveness and efficiency of communicating scientific information to stakeholders with diverse scientific backgrounds. I draw upon psychology and formal and informal education models used to understand the uptake of scientific information in sub-sectors of the public, and identify gaps within the existing literature that preclude the immediate application of existing models to the context of scientific fisheries information and fisheries stakeholders. The first data chapter in this thesis identifies variables influencing the informal learning of scientific fisheries information by fisheries managers, researchers and commercial and recreational fishers. Using semi-structured interviews and content analysis, I confirm that the cognitive, conative and affective dimensions used to describe informal learning in the literature apply to fisheries stakeholders. I also identify two constraints: investments of time, and investments of money. In the second data chapter, I demonstrate the mapping of the relationships between these variables using a Fuzzy Cognitive Mapping (FCM) approach to mental models. I show that by combining the FCM approach with network analysis techniques, it is possible to illustrate the relative importance of each variable, whether it is acting as a driver or a constraint, and how closely the variables relate to one another. I also demonstrate that individuals' initial levels of interest in a topic significantly influence their willingness to informally learn more about that topic. Specifically, when fishers are less interested in a topic, their mental models and the relationships between the variables are simpler than when their initial interest is piqued. My third and final data chapter uses network analysis to identify pathways through which the communication of scientific information to fisheries stakeholders could be made more efficient. I examine whether information sources' formats or the authorities they represent affect the likelihood of stakeholders relying upon them, and employ network analysis metrics to identify strategic targets that could benefit communication programs aimed at specific stakeholder groups. The results indicate that the ideal outlet for communicating science to fisheries stakeholders is likely to vary depending on the content and context of the information to the individual, to the degree that in some cases, a stakeholder's primary role has no significant effect.

Acronyms

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
EBFM	Ecosystem-Based Fisheries Management
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBR	Great Barrier Reef
FCM	Fuzzy Cognitive Mapping
ICCM	Informal Conceptual Change Model

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1. Introduction

1.1 Background

Modern fisheries management is heavily dependent on the outputs of scientific inquiry to inform policy and regulation. Prior to the mid-1980s, fisheries management was primarily informed by the natural sciences (i.e. biology, ecology). However, recent changes in the way fisheries are conceptualised and managed have highlighted the inadequacies of a reliance on the natural sciences, resulting in a more interdisciplinary approach (including the social sciences) to fisheries science and management. Concurrent with the increasingly multidisciplinary nature of fisheries management, there has also been a move towards increasing the engagement of a wider range of stakeholders in the fisheries management process (Johannes, 1981; Freeman et al., 1991; Berkes et al., 1995; Nielsen and Vedsmand, 1995; Jentoft et al., 1998; Granek et al., 2008; Ramírez-Monsalve et al., 2016).

Collectively, these recent changes to the way fisheries are conceptualised and managed have implications for the way scientific information is communicated and utilised within a fisheries management context. Science communication is no longer primarily about communicating the results of fisheries biology and ecology to a relatively small group of fisheries managers. However, little is known about how information from a range of scientific disciplines (social, economic, and ecological) can be communicated effectively to a diverse range of fisheries stakeholders (commercial and recreational fisheries, fisheries managers, seafood consumers etc.). Despite the need for a better understanding of issues surrounding science communication, uptake[1], and adoption in modern fisheries management, this is an area that has received little formal attention.

Very little is understood about how fisheries stakeholders with a wide variety of educational and scientific backgrounds assess and uptake scientific information. Without a knowledge of how the various fisheries stakeholders uptake scientific information, it is difficult to maximise the efficiency and effectiveness of any communication efforts. There are no existing models in the literature that directly address how fisheries stakeholders uptake scientific information. A number of models exist in informal learning and public understanding of science literature that could be adapted to the fisheries context. However, since the uptake of scientific information is highly contextual, these existing models and variables can only be considered a guide (Shrigley et al., 1988; Alsop, 1999; Fensham and Harlen, 1999; Critchley, 2008). This thesis seeks to address the

[1] From here on, the word uptake refers to the internalising of information i.e. Uptake has occurred once an individual has incorporated the new information into their existing knowledge.

knowledge gap surrounding how scientific information can be communicated more effectively and efficiently to relevant fisheries stakeholders by: 1) identifying the variables driving and constraining the informal learning of scientific information by fisheries stakeholders; 2) modelling the relationships between the variables identified as influencing informal learning; and 3) and identifying information sources shared among stakeholders where communication efforts could be focused.

1.2 Thesis objectives

The overarching aim of this thesis is to develop ways to optimise fisheries stakeholders'[2] uptake of scientific information in a fisheries management context.

To achieve this overarching aim, the research presented in this thesis seeks to achieve the following objectives:

1. Establish further research into the communication of scientific information to and among fisheries stakeholders as necessary in modern fisheries management.

2. Identify variables important for fisheries stakeholders' informal learning of scientific fisheries information.

3. Develop a model of the complex relationships between variables controlling/constraining fisheries stakeholders' uptake of scientific information in a way that could be informative for communicators.

4. Map stakeholders' usage of existing information sources to identify information pathways that could make future communication efforts more efficient.

1.3 Thesis structure

This thesis consists of seven chapters. This first chapter is an introduction to the thesis, and an outline of the thesis structure. Chapters Two and Three are presented as literature reviews that set

[2] From here on, the term 'fisheries stakeholders' refers to those who primarily identify themselves as being fisheries managers, researchers or commercial or recreational fishers. These stakeholders have been sampled for this thesis owing to their diverse roles and scientific backgrounds. Technically, all individuals with an interest in fisheries are fisheries stakeholders; however, as fisheries managers, researchers and both commercial and recreational fishers are the main actors in fisheries management, and for ease of navigation through the literature, only they are included in the definition. Also, the term 'fishers' includes both commercial and recreational fishers in its definition.

the context and develop the theoretical foundations of this research. The fourth, fifth and sixth chapters of this thesis are written as stand-alone journal articles based on the collection and analysis of original data from a number of surveys of fisheries stakeholders in the Great Barrier Reef region of Queensland, Australia. The following lists the objectives presented above, and how the chapters in this thesis achieved those objectives:

1. *Establish further research into the communication of scientific information to and between fisheries stakeholders as necessary in modern fisheries management.*

This objective is achieved by Chapter Two, which presents a literature review discussing how changes to the way fisheries are conceptualised and managed have made the communication of scientific information between and among stakeholder groups a greater issue worthy of further scientific investigation. This chapter discusses the following topics with relevance to the ways they affect the way fisheries stakeholders are communicated to/with: the shift from highly centralised fisheries management to ecosystem-based fisheries management (EBFM); the changing roles of fisheries stakeholders; and the corresponding shifting importance of information from the multiple scientific disciplines[3] currently informing fisheries management.

2. *Identify variables important for fisheries stakeholders' informal learning of scientific fisheries information.*

This objective is achieved by Chapters Three and Four. Chapter Three reviews existing literature about the communication of scientific information to sectors of the public, and identifies variables, concepts, models and theoretical frameworks that could inform investigations into modelling the informal learning of scientific information among fisheries stakeholders. This chapter establishes informal learning as the theoretical framework on which this thesis and its investigations are based and culminates in the creation of a potential hypothetical model of fisheries stakeholders' uptake of science. Chapter Four tests the applicability of the variables identified in Chapter Three as being potentially important drivers/constraints of fisheries stakeholders' informal learning by applying content analysis techniques to survey data gathered from fisheries stakeholders in the Great Barrier Reef region in Queensland, Australia. Potential

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[3] From hereon in, the scientific disciplines considered to be informing fisheries management in multi-disciplinary fisheries management include the natural and social sciences, and any other scientific disciplines (e.g. climate, hydrological, geo-physical etc.), so long as the information is relevant to the management of that fishery. No distinction is made between the social sciences and natural/physical sciences, or any other disciplines unless it is explicitly stated.

additional, relevant variables not identified in the literature were also investigated in Chapter Four.

3. *Develop a model of the complex relationships between variables controlling/constraining fisheries stakeholders' uptake of scientific information in a way that could be informative for communicators.*

Recreational fishers were used as a pilot group in Chapter Five to trial novel research methodologies developed to achieve this third objective. Recreational fishers were chosen as the pilot group because of their ease of sampling: Relative to fisheries managers, scientists and commercial fishers, it was considered more expedient to sample a large enough number of recreational fishers to meaningfully test the new methodology developed in this chapter. The complex relationships between the variables identified in Chapters Two and Three as drivers/constraints of fisheries stakeholders' informal learning using a modified Fuzzy Cognitive Mapping (FCM) approach to mental modelling were mapped in Chapter Five. The results of this chapter include a series of mental models illustrating recreational fishers' thought processes when appraising whether they wish to informally learn more about a piece of scientific fisheries information. Network analysis techniques were also employed to lend more rigour to the analysis of the FCM representations of fishers' mental models. The resultant FCM representations of fishers' mental models were also analysed using network analysis techniques, lending more rigour to the interpretations of the mental models.

4. *Map stakeholders' usage of existing information sources to identify information pathways that could make future communication efforts more efficient.*

Chapter Six was designed to fulfil this fourth and final objective. Network analysis techniques were used in this chapter to map the information sources used by fisheries stakeholders and identify any shared information sources and common traits between information sources that might have led to them being shared or used differently between stakeholders.

Finally, Chapter Seven, the discussion chapter, summarises the theoretical and applied contributions of each of these chapters. In Chapter Seven, the findings of the component chapters of this thesis are placed in the context of current literature and recommendations for future research into this area are presented.

2. Understanding issues surrounding the communication of scientific information in fisheries management: an introduction and literature review

This chapter contributes towards the major aim of this thesis by setting the context and achieving objective one:

Establish further research into the communication of scientific information to and between fisheries stakeholders as necessary in modern fisheries management.

The chapter does this by presenting evidence that there is a mismatch between the way science is communicated in fisheries, and the way the conceptualisation and understanding of fisheries systems has changed over the past 30 years. Issues complicating the communication of science to various fisheries stakeholders are discussed, and a case is made for the need for studies that could make the communication of scientific information to fisheries stakeholders more effective and efficient.

In this chapter, I discuss how changes to the way fisheries are conceptualised and managed have made the effective communication of scientific information to stakeholders a great necessity. I examine the implications of those changes for the communication of scientific information in modern fisheries systems. I argue that there have been three major changes to how fisheries management is approached that have had important implications for the communication of scientific fisheries information: 1) the move away from highly centralised fisheries management towards ecosystem-based fisheries management (EBFM); 2) the changing roles of different scientific disciplines; and 3) the changing roles of fisheries stakeholders.

2.1 The move from highly centralised fisheries management to EBFM

The recent shift from highly centralised to systems-based modes of fisheries management such as EBFM is one of the strongest drivers of change to the way science is communicated in fisheries management systems. Over the past 30 years, the fisheries management approach has changed from being largely informed by single species biology-based research towards more holistic modes of management incorporating concepts of the social-ecological system and adaptability (Jentoft, 1989; Nielsen and Vedsmand, 1995; Sen and Nielsen, 1996; Pomeroy and Berkes, 1997; Jentoft et al., 1998; Pauly et al., 2002; Ward et al., 2002; Kaplan and McCay, 2004; Pikitch et al., 2004; Armitage, 2005; McPhee, 2008). Prior to the mid to late 1980s, fisheries management in

Westernised/industrialised countries was highly centralised: fisheries managers (including those at executive and political levels) held most of the power and influence in fisheries decisions. During this era, management decisions were mostly informed by the biological/ecological sciences and economics (Soule, 1985; Clay and Goodwin, 1995; Armitage, 2005). Fisheries were traditionally managed on a localised species basis to maximise economic return (McPhee, 2008). Little emphasis was placed on understanding the human dimensions or engaging fishers in the management process beyond informing stakeholders after management decisions were made. Fishers and other resource users were largely seen as being outside of the system being managed (Endter-Wada et al., 1998; McPhee, 2008). In the fisheries context, science communication was primarily about informing fisheries managers about the results of biological research and the implications of those results for fisheries management. When communication was undertaken with other stakeholders, it was primarily about informing fishers about management changes and decisions that were already made. The lack of emphasis placed on communicating scientific information to fishers and engaging them in fisheries management prior to the mid-1980s is reflected in the lack of literature on the subject before that date.

During the mid-1960s through to the early 1990s, several major fisheries collapsed under traditional, centralised management regimes, resulting in public distrust of fisheries management and the public perception that fisheries management had failed (Clay and Goodwin, 1995; Jentoft et al., 1998; Smith et al., 1999). Examples include four stocks of Atlantic Herring, the Californian stock of Pacific Sardine, South African stocks of South-east Atlantic Pilchards, Peruvian Anchoveta stocks on the West coast of South America, the Capelin stocks of the Barents Sea, Pacific Mackerel stocks in California and, probably the most famous example, the Newfoundland Atlantic Cod fishery (Beverton, 1990; Hutchings and Myers, 1994).

In response to highly publicised fisheries collapses and identified deficiencies in fisheries management, the concept of ecosystem-based management began to gain popularity in the mid-1980s. Ecosystem-based management involves understanding a natural resource and its multiple uses in the context of the system in which it exists (Soule, 1985; Clark, 1992; Kessler et al., 1992). A more recent definition of ecosystem-based management describes it as an integrated and science-based approach to the management of natural resources that focuses decision making on sustaining the health of an ecosystem, rather than solely on the goods and services derived from the system (Gray and Jordan, 2010). Fisheries and human activity are inseparable, and fisheries management largely involves managing the effects that human activities have on fish stocks and fish habitat. Therefore, a push towards EBFM means a push towards understanding the social component of fisheries (Clay and Goodwin, 1995). Fishers and other stakeholders are no longer seen as outside of the natural system, but as integral parts of the system that need to be considered in management (Moran, 1990; McDonnell and Pickett, 1993; Slocombe, 1993; Human-

Dimension-Study-Group, 1994; Clay and Goodwin, 1995; Gunderson et al., 1995; Harwell et al., 1996; Mangel et al., 1996; Pomeroy and Berkes, 1997; Jacobson and McDuff, 1998; Ewel, 2001; McPhee, 2008).

The late 1980s saw the popularity of EBFM grow and the recognition that fisheries management needed to adapt to ecosystem changes more readily. If fisheries appeared to decline, management regulations needed to change accordingly to prevent fishery collapse. Blame for a fishery's collapse was no longer assigned to natural phenomena alone (as it was in the collapse of the Newfoundland cod fishery), but to an agency's lack of scope and their inability to detect and react to the decline of a fishery in a timely manner (Steele et al., 1992). The nature of EBFM however, means an increase in the amount and kinds of data needed to inform management decisions.

One style of management that complements EBFM and is also increasing in popularity is active-adaptive management. Active-adaptive management lends itself to dealing with large amounts of information and reacting to it. Active-adaptive management allows agencies to actively adapt to perceived risks, and is now one of the most common practices in fisheries management in Westernised/industrialised countries. Active-adaptive management is an umbrella term describing any management style that allows the adaptation of management regulations to perceived risks. Highly centralised management styles can be practised using an active-adaptive approach, as can highly decentralised management styles such as co-management and community-based management. Whichever management style that active-adaptive management is applied to, it still requires the effective engagement of resource users. Input from resource users is indispensable if the amount of information necessary for active-adaptive management to function effectively is to be acquired.

The adoption of active-adaptive management and EBFM has two important implications for the communication of scientific information in fisheries management. First, scientific fisheries information now needs to be communicated to a broader stakeholder base than in traditional regimes. This broader base includes those who directly use fish populations (e.g. commercial and recreational fishers) and those who do not directly use fish populations (e.g. consumers, conservation NGOs, local communities etc.). The approach taken to communicate scientific information under traditional regimes (i.e. communicating science between scientists and fisheries managers) is unlikely to be adequate for ensuring effective communication of scientific information to a broader range of stakeholders. Second, there is a growing need to effectively and efficiently communicate scientific information from a range of different disciplines (e.g. biology, social science, economics etc.) in fisheries management. Thus far, there has been little formal investigation into communicating the results of non-traditional types of information (i.e. social science) effectively within a fisheries management context. Additionally, evidence that the results of social science inquiry are not taken up and used in fisheries management decisions to the same extent as natural science suggests that effective communication of such information in a fisheries context may be problematic (Clay and Goodwin, 1995; Endter-Wada et al., 1998). These two implications are discussed more fully in the following sections.

2.2 The changing role of fisheries stakeholders

With the increasing adoption of multidisciplinary and interdisciplinary approaches, fisheries management is changing to better understand and cater for the needs of fishers. The effective practice of active-adaptive management also relies on maintaining good levels of engagement with fishers. Moving towards EBFM and active-adaptive management means a greater emphasis on understanding fishers' needs and their use patterns. With the understanding that fisheries are complex socio-economic systems comes the growing need to collect data from fishers and engage them in fisheries management. Local knowledge contributed by fishers makes it easier for fisheries managers and researchers to understand use patterns and monitor the fishery without massive expenditure (Granek et al., 2008). Involving and engaging fishers in fisheries management has several implications. If fishers are engaged and involved positively, the sense of stewardship that they gain can mean that they actively engage in conservation efforts (Granek et al., 2008). However, as they become more involved in fisheries management, fishers also hold more sway in decision making processes, meaning that less power is held by researchers and managers. This section discusses how the role of resource users has changed since the mid-1980s, and what this means for fisheries management and the communication of scientific information that informs it.

Until the mid-1980s, managers and researchers played a greater role in fisheries management than the resource users. Researchers collated data from resource users and conducted their studies before communicating the results to fisheries managers. Fisheries managers then decided upon the appropriate course(s) of action based on the available data (Soule, 1985; Clay and Goodwin, 1995; Armitage, 2005). Fishers were consulted occasionally, but usually not given much power in fisheries management and were generally only informed once decisions were made and regulations were in place. In many fisheries, fishers now hold more power than they did before the mid-1980s (Granek et al., 2008; McPhee, 2008). There are two reasons for this shift in power: First, the move towards EBFM implies that fishers need to be better understood and engaged with if the fisheries resource is to be managed effectively; Second, fishers as a whole are now more organised and politicised than they were during the 1980s (McPhee et al., 2002). Organised groups that fishers feel voice their interests give fishers an official presence in fisheries management. Because EBFM requires their contributions for success, and they have more of an official presence, fishers are pushing for more meaningful engagement in fisheries management.

Adopting a management strategy that places an emphasis on increasing the level of engagement with the fisher community demands good communication between all parties involved (i.e. managers, researchers and fishers) (Jacobson and Robinson, 1990; Janssen and Goldsworthy, 1996; Hisschemöller and Midden, 1999; Ruth et al., 2005; Frank et al., 2009). Effective communication is thought to enhance levels of engagement and the quality of contributions from the community during public consultations (Jacobson and Robinson, 1990; Janssen and Goldsworthy, 1996; Hisschemöller and Midden, 1999; Ruth et al., 2005; Frank et al., 2009). High levels of communication and therefore better understanding between all parties involved may also reduce conflict, or at least result in constructive conflict (Burkardt et al., 1998; Burger et al., 2001).

The resource user focus of EBFM has important implications for the role of fishers in fisheries management and also for communicating science in a resource management context. Scientific information can no longer be communicated solely between managers and researchers. The engagement of fisheries resource users requires effective communication to a wide range of audiences with different values, perceptions and relationships with fisheries resources. Avenues outside of the traditional scientific and bureaucratic formats for communicating scientific information in fisheries management need to be explored if fishers and other fisheries resource users are to be communicated and engaged with effectively.

2.3 The changing importance of scientific disciplines in fisheries management

As traditional, highly centralised fisheries management gives way to EBFM, the nature of the scientific information informing management decisions also changes. Modern fisheries management has traditionally depended on science to inform its decisions. Scientific information informing fisheries management includes age/size/sex models, ecological surveys, telemetry, life history, catch rates etc. (Hutchings and Myers, 1994; McPhee, 2008). Catch rates are compared with those of the past and combined with stock assessments to arrive at allowable quotas for commercial fisheries. Size/age/sex structures inform the setting of bag and size limits for recreational fishers. The natural sciences are fundamental to fisheries management, and this is why natural scientists have traditionally been major informers of fisheries management, and why fisheries managers also often have a natural science background (Soule, 1985; Ludwig, 2001; Armitage, 2005). While the social sciences are increasingly relevant to modern fisheries management, they were not well used in fisheries management prior to the mid-1980s.

The collapse of several large, industrialised fisheries over the past three decades highlighted the fact that fisheries are complex, social-economic systems requiring an interdisciplinary approach to their research and management (Clark, 1992; Clay and Goodwin, 1995; Endter-Wada et al., 1998; Smith et al., 1999). One of the more famous examples is the Newfoundland cod fishery. In the case of the Newfoundland cod fishery, researchers and managers held all the scientific knowledge and relied heavily on complex biological models to set catch quotas (Steele et al., 1992). Despite early warnings of imminent collapse from fishers, scientists and managers were unwilling and unable to incorporate local knowledge and other social science information into the fisheries models (Steele et al., 1992). The concerns of local fishers and their proposals were ignored and the fishery collapsed, resulting in the loss of one of the world's largest fisheries and over 30,000 jobs (Steele et al., 1992). To prevent fisheries collapsing in a similar manner to the Newfoundland cod fishery, the modern approach to fisheries management is now often informed by a much wider range of scientific disciplines than in the past (Clark, 1992; Clay and Goodwin, 1995; Endter-Wada et al., 1998).

Using an EBFM approach requires that fisheries be viewed as social-ecological systems. Understanding the human component is integral to understanding how fisheries social-ecological systems function. With the EBFM approach has come a recognition that the social component of the social-ecological system is as complex as the ecological component (Mare, 1998; Armitage, 2005). Harvesters, buyers, processors, wholesalers, retailers and support industries such as fuel, ice and equipment suppliers, families, communities, scientists, managers, legislators and administrators are increasingly included in models for commercial fisheries (Clay and Goodwin, 1995). Accordingly, models for recreational fisheries have become equally complex. Models for recreational fishers' behaviours now include many variables including family, peers, economic climate and ecological values among others (Clay and Goodwin, 1995; Jentoft, 2000). Natural resources have multiple user groups with different wants, needs, intentions, behaviours and opinions, and all must be accounted for and involved if possible if the resource is to be managed in a manner that benefits all (Clay and Goodwin, 1995; Grimble and Wellard, 1997; Granek et al., 2008; Frank et al., 2009). Attempts to model social-ecological systems are also not confined to fisheries systems alone (Grimble and Wellard, 1997). Therefore, to ensure an accurate understanding of fisheries as social-ecological systems, it may be necessary to investigate, test and incorporate data on the multiple dimensions of social-ecological systems outside of the fisheries context. This need to incorporate information from a wide variety of social-ecological contexts creates an even greater need to improve the efficiency and effectiveness of the transfer of scientific information in the fisheries management context.

To deal with the need for the transfer of multidisciplinary scientific data, the communication of scientific information in fisheries management needs to become more adaptable and proficient. Because biological data have traditionally played a large part in informing fisheries management, avenues for communicating scientific information within fisheries management already exist. Two major problems exist, however. The first is that social data are often not held in the same esteem as biological data in fisheries management (Endter-Wada et al., 1998; Jacobson and

McDuff, 1998; Ludwig, 2001). Fisheries managers are often from a natural science background, and natural sciences are familiar to them; less familiar social data are often not assigned enough credibility in management agencies (Clay and Goodwin, 1995; Endter-Wada et al., 1998). There is a clear need to investigate how social science is perceived and how best to communicate it in fisheries management. Currently, few data are available describing the differences or similarities between the stakeholder perceptions of natural and social sciences in fisheries management. Second, the move towards less centralised styles of fisheries management means an increased emphasis on fisher engagement and consultation. However, fishers are unlikely to react to, uptake and use information in the same way as researchers and managers. Understanding how fishers and other stakeholders perceive and uptake scientific information will become more important as their role in fisheries management grows.

2.4 Conclusion

An EBFM approach to fisheries management requires good communication between all fisheries stakeholders. Researchers, managers and, ultimately, resource users, stand to benefit from the effective and efficient communication of multidisciplinary data. Furthermore, an avenue for open communication with the public is vital for the success of non-centralised natural resource management (Jacobson and Robinson, 1990; Janssen and Goldsworthy, 1996; Hisschemöller and Midden, 1999; Ruth et al., 2005; Frank et al., 2009). It is apparent that there is a need to understand how multidisciplinary scientific information can be communicated reliably, effectively and efficiently to stakeholders with a broad range of scientific backgrounds.

The following chapter, Chapter Three, takes the next step towards achieving the major aim of this thesis. In Chapter Three, the literature is examined for information that could inform the construction of useable models. Specifically, existing variables and frameworks that could be used to facilitate the goal of finding ways to optimise fisheries stakeholders' uptake of scientific information are reviewed.

3. The application of public understanding of science, informal learning and science communication theory to the fisheries context

The previous chapter set the context for this study, establishing the need for research informing the effective communication of scientific information in fisheries management, and discussing some of the issues that have arisen due to changes to the way fisheries are conceptualised and managed. The theoretical framework for this thesis is set in this chapter.

This chapter contributes to this thesis' overarching aim by achieving objective two:

Identify variables important for fisheries stakeholders' informal learning of scientific fisheries information.

The existing literature is reviewed for existing variables, concepts, models and theoretical frameworks, which are assessed for their applicability to the communication of scientific information to and between fisheries stakeholders. A hypothetical, theoretical model is proposed based on the current literature, and knowledge gaps regarding the communication of scientific information to fisheries stakeholders are also identified.

An avenue for open communication with the public is vital for the success of non-centralised, ecosystem-based natural resource management (Jacobson and Robinson, 1990; Janssen and Goldsworthy, 1996; Hisschemöller and Midden, 1999; Ruth et al., 2005; Frank et al., 2009). The effective communication of scientific information minimises conflicts arising from misunderstandings, or due to scientific information being presented out of context (Burkardt et al., 1998; Burger et al., 2001). This review explores existing public understanding of science and informal learning literature, and draws relevance between the concepts identified in this literature and the fisheries context. Existing models describing the uptake of scientific information in sectors of the public and their components are examined for their applicability to the fisheries context using comparisons with real-world case studies. Finally, a hypothetical theoretical model is proposed based on the relevant variables identified in the literature, and an argument is made for the use of informal learning as the theoretical framework for this thesis.

3.1 Accessibility

One major issue that arises repeatedly in the public understanding of science and human dimensions of wildlife literature is that of the accessibility of scientific information to stakeholders. Two major types of accessibility are discussed in the sections below: physical and cognitive. In the context of this thesis and review, physical accessibility describes the ease with which individuals can physically expose themselves and/or be exposed by others to new scientific information. Cognitive accessibility describes the ease with which individuals can mentally engage with and accurately consume new information, should they decide to.

The issue of accessibility is discussed first in this review, since the initial stages of communication involve ensuring the physical and cognitive accessibility of the information. If information is physically hard to access, it is unlikely that it will be sought out (e.g. a fisher might have difficulty sourcing scientific papers). If the information is cognitively inaccessible (i.e. the information is too hard to understand or is incompatible with existing senses of logic or knowledge sets), or considered invalid, it might be dismissed or misunderstood. Despite the fact that managers and researchers might be expected to be more comfortable dealing with information in rigid bureaucratic and scientific formats owing to their respective roles and responsibilities, evidence suggests that even these stakeholders struggle with information outside their own training (Bauer, 1992; Berkenkotter and Huckin, 1995; Jacobson and McDuff, 1998; Cvitanovic et al., 2014). Fishers are at an even greater disadvantage. As a widespread – and less formally organised – stakeholder group, fishers generally communicate informally, and can find highly formal bureaucratic and scientific formats alienating (Wynne, 1993). Nevertheless, fishers do appear interested in accessing scientific information despite the difficulties they might face accessing it both physically and cognitively (Li et al., 2010). The following sections describe ways to conceptualise physical and cognitive accessibility and their implications for the communication of scientific fisheries information in more detail.

3.1.1 Physical accessibility

Physical accessibility is one of the foremost concerns when ensuring effective communication. Without physical access, all other concerns are moot. One concept used to describe the public's physical access to information is the mediasphere. The mediasphere is the conceptualisation of the way people are exposed to many forms of media from all angles every day. All media is included in the mediasphere; from the usual mediums such as newspapers, magazines and television, to social media such as internet forums, Facebook, Twitter etc. From a fisheries perspective, the mediasphere includes government websites relevant to fisheries management, brochures/media releases from fisheries management agencies, fishing magazines, fishing shows on television, fishing forums etc.

As members of the public, fishers get most of their scientific information about natural resource management issues through the mass media, although this coverage is often superficial and irregular (Gerbner et al., 1981; LaFollette, 1990; Nelkin, 1995; Strang and Soule, 1998; Bengston et al., 1999; Nisbet et al., 2002; Antilla, 2005). Scientists were and still are sources of scientific information for the public, appearing at public events or on television or publishing journalistic articles (McDuff, 1999; Andrews et al., 2005). Growing numbers of specialised science journalists also provide scientific information for the public (Friedman et al., 1986; Metcalfe and Gascoigne, 1995; Conrad, 1999; Treise and Weigold, 2002; Meyer, 2006). Science journalists research new scientific findings, interview scientists and report news to the public, often publishing more detailed articles in specialised publications such as *New Scientist* (Friedman et al., 1986; Conrad, 1999; Dayton, 2006; Meyer, 2006). Additionally, most fisheries management agencies in developed countries maintain active websites through which the results of relevant and recent studies can be easily accessed free of charge. Therefore, it would appear that the infrastructure exists to circumvent physical access issues presented by pay-walls etc. to fishers seeking high quality scientific information. However, the sheer amount of information fishers are being exposed to via the mediasphere means that there can be confusion, and miscommunication, causing misunderstanding and conflict.

With the proliferation of highly mediated, easily accessed information sources, come issues of objectivity and quality control. In an age when people are surrounded by competing sources of information in multiple formats, outsiders can find it difficult to distinguish between information reported objectively and that which is reported with particular objectives in mind. The problem is exacerbated when science, or particular science topics, becomes politicised and commercialised and biased articles become more common. Biased articles pertaining to controversial natural resource management issues are likely to cause confusion and conflict among fisheries stakeholders where these problems might not have existed before (Weeks and Packard, 1997). The recent proliferation of social media also has major implications for the communication of unbiased scientific information. It is now very easy for misinformation to travel through a community. The issue is no longer necessarily about stakeholders' ability to physically access information about fisheries, but how to ensure they are accessing accurate information. In an effort to ensure stakeholders can access accurate and correct scientific information, many natural resource management agencies now operate Facebook pages and maintain social media presences. Through these social media accounts, these agencies are reaching thousands of their stakeholders at once and addressing questions and issues directly to avoid misinformation. Because the adoption of social media by resource management agencies is a relatively recent development, the actual efficacy of these efforts (i.e. stakeholders' levels of uptake) is still largely unknown. Any efforts fisheries agencies make to improve stakeholders' physical accessibility to correct information are laudable. However, the issue of whether the information is cognitively accessible to the target audience is harder to address.

3.1.2 Cognitive accessibility and validity

Cognitive accessibility and validity are harder to provide than physical accessibility. To be cognitively accessible, scientific information needs to be presented in a manner that makes sense to the target audience. Cognitive validity requires that the information is considered to be true, reputable and worth retaining by the target audience. The information being presented needs to be more than simply understood. For example, scientific information presented in journalistic formats may not be considered valid to managers or researchers who prefer scientific information to be communicated through reports, summaries, peer-reviewed papers and government documents written by researchers. Correspondingly, fishers introduced to new information that conflicts with their existing understandings of a fishery have also been known to reject it despite clearly understanding the content of the message (Degnbol, 2005). In science-policy literature, the cognitive dimension is included in the 'credibility' attribute of the CRELE framework (i.e. Credibility, Relevance and Legitimacy), which is used to evaluate the effectiveness of the uptake and use of scientific information on the science-policy interface. In this context, 'credibility' describes how policy makers perceive the quality, validity and scientific adequacy of the scientific information (Sarkki et al., 2013, 2015).

One concept used in the cognitive sciences to describe making information more cognitively valid, is 'framing'. Frames are described as unconscious structures including a person's perceptions of their role in a real or imagined situation, relations to those roles, and relations to other frames (Lakoff, 2010). A piece of information necessarily needs to pass through these frames before it can be internalised, and incorporated into a person's knowledge, perhaps forming a new frame (Lakoff, 2010). Previous studies have shown that the perceived accuracy of scientific findings are often related to how well the information fits into a person's psychological 'frames' (Campbell and Kay, 2014). Therefore, how a piece of scientific information is 'framed' is likely to affect how cognitively accessible and valid it is to an individual.

The construction of messages can therefore affect a piece of information's cognitive accessibility and validity independent of the format used to present it. For example, information that is presented using highly academic, scientific language is likely to be more cognitively accessible and valid to researchers and managers than it might to commercial and recreational fishers, regardless of whether it is presented using primary literature or social media. Conversely, that same information presented using more journalistic or informal language through the mass media, or via a social media platform might face greater scrutiny from academically trained researchers and managers than it otherwise might have if presented in the manner of the previous example.

No single format will provide for the physical accessibility needs of all fisheries stakeholders. Likewise, no one way of constructing a message or presenting information will fulfil the cognitive needs of all fisheries stakeholders. A number of outlets and modes of messaging will need to be explored if the desired level of science communication is to be achieved in EBFM. To maximise the effectiveness of these outlets, the variables controlling the uptake of scientific information need to be explored. The factors that govern the uptake of scientific information will be discussed in the following sections.

3.2 Uptake of science in fisheries management

The ideas behind how science should be communicated to sectors of the public have also evolved over the past 30 years. The traditional model assumed scientific knowledge was the pinnacle, and claimed that the public should recognise this, and adopt it in favour of their existing 'lesser', un-scientific knowledge (Gerhards and Schäfer, 2009). The traditional model simply strove for the public's understanding of science, and insisted that the public could be made more knowledgeable about science if the mass media simply translated scientific information and published it in a public avenue. This model was also uninterested in public discourse regarding science, and considered any controversy or discussion among the public of no value (Gerhards and Schäfer, 2009). In essence, this first model shares many assumptions with the deficit model described in the next section.

Since then, evidence that the traditional model fails to capture the complexity of individuals' uptake of scientific information has accumulated, and more progressive models have been developed. These models acknowledge that non-scientific knowledge also has value, and plays an important role in relationships with scientific messaging (Weeks and Packard, 1997; Alsop, 1999; Armitage, 2005; Degnbol, 2005; Granek et al., 2008; Gerhards and Schäfer, 2009). Additionally, these models strive for public engagement with science and technology (as opposed to the informing of the public alone), and messaging based on these models seeks to appeal to the target audience's sense of relevance and encourage their participation in the discourse surrounding scientific information (Wynne, 1993; Alsop, 1999; Fensham and Harlen, 1999; Gerhards and Schäfer, 2009). This thesis, guided by these more progressive models and their ideals, seeks to improve the understanding of how best to communicate scientific information to fisheries stakeholders so that they can engage with it, and participate in an open discourse surrounding it.

Understanding how people appraise, engage and uptake scientific information is pivotal to successful communication. However, owing to the complex thought processes involved, and the complex relationships between different kinds of knowledge, uptake of the information is difficult to ensure. Science communication professionals deliver scientific information pertaining to a range of subjects in a variety of formats to the public. However, even with their proficiency in translating scientific jargon into accessible layman's terms, and excellent writing/presenting skills, science communicators cannot always confidently predict how widely held preconceptions or the mass media might alter a reader or consumer's perceptions of the scientific information being presented and, therefore, whether someone is likely to uptake the new information (Treise and Weigold, 2002). Understanding the intended audience's perceptions of scientific information and how they uptake it is an important first step towards improving the transfer of scientific information. Differing perceptions of scientific information have been shown to present problems in natural resource management systems (Wynne, 1993; Cunningham et al., 1994; Hisschemöller and Midden, 1999). If researchers, managers and science communicators do not deal with the differences in their perceptions of what scientific information is and how best to communicate it, the end result could be a disjointed message and a perceived lack of consensus, leading to distrust by the public (Wynne, 1993; Cunningham et al., 1994; Hisschemöller and Midden, 1999). Public understanding of science, media studies, psychology, and informal and formal learning literature contain studies aimed at describing, understanding and assessing variables effecting people's uptake of scientific information. This aforementioned literature also contains information about issues associated with measuring the uptake of scientific information, the previously popular deficit model, the concept of informal learning and has the potential to inform the development of a new model describing fisheries stakeholders' informal uptake of scientific information.

3.2.1 The deficit model

Until the mid-1980s, the deficit model was used to describe the relationship between a community's attitudes towards science and their exposure to scientific information. The deficit model is a simple model that states that if information is supplied to the public, who are lacking that information, the information will be passively taken up, and enlightenment will occur as an inevitable consequence. In the fisheries context, this enlightenment implies that stakeholders will come to understand and support science-based management. The model is based on assumptions that the public is ignorant of science, and that they need only be supplied with the necessary information (regardless of its format or presentation), to become enlightened and therefore supportive of science-based management decisions. The model also assumes that fisheries manages and researchers act exclusively as the sources of scientific information that the public is deficient of. This assumption has never been less true. In the light of a shift towards a more interdisciplinary and active-adaptive approach to fisheries management, scientists and managers are now very often the consumers of new scientific information from fields outside of their own expertise. Finally, the deficit model assumes that the uptake of scientific information by the public is passive, and that making the scientific information more available to them will be sufficient to achieve the goal of a more scientifically knowledgeable and compliant public.

The deficit model is deficient on several levels. First, it implies that the public is ignorant and therefore it fails to acknowledge the value of the public's existing knowledge. In a fisheries management context, ignoring fishers' knowledge is counter-intuitive, and counter-productive (Weeks and Packard, 1997). The deficit model also fails to address how fisheries stakeholders make sense of scientific information within their existing knowledge sets (Sturgis and Allum, 2004). Assuming that fishers' existing knowledge is inadequate or irrelevant to understanding the logic behind management decisions can lead to communications to fishers being delivered in an inadvertently patronising and alienating manner (Weeks and Packard, 1997). There is evidence to suggest that some fishers agree with the principles and science behind decisions made in fisheries management but have different opinions on how the problem should be solved. For example, when managers put protected areas in place to allow fish stocks to replenish, conflict can occur if the fishers do not agree that putting protected areas in place is the best practice. These fishers might agree with the need to protect fish stocks to some level so that they can replenish, but see protected zones as doing little more than limiting their fishing grounds. The fishers do not disagree with limiting their take of certain fish species to ensure the sustainability of their fishery, but do not believe that protected areas are the best way to do so (Clay, 1993). Patronising and alienating an entire stakeholder group is likely to create conflict, and may result in stakeholders refusing to partake in any further consultations or communication efforts (Wynne, 1992; Clay, 1993). Resource users' knowledge is becoming increasingly valued and a new model describing their uptake of scientific information needs to allow for their existing knowledge (Johannes, 1981; Freeman et al., 1991; Clay, 1993; Wynne, 1993; Evans and Durant, 1995; Weeks and Packard, 1997; Alsop, 1999; Berkes et al., 2000; Degnbol, 2005; Gray and Jordan, 2010).

Second, the deficit model assumes that scientific information will be passively absorbed by the 'ignorant' public. However, the average person is more capable of reasoning than formal surveys often demonstrate. The uptake of scientific information is often a decision arrived at by individuals based on multiple variables including scientific literacy, their own personal morals and ethics, the compatibility of the information with their own knowledge, the importance they assign to that information, the amount of power held by the individuals in fisheries management, and the relationship between the individuals and the source of the information (Wynne, 1992; Wynne, 1993; Alsop, 1999; Fensham and Harlen, 1999; Osborne et al., 2003). Consequently, individuals' decisions to uptake new scientific information are often reasoned and conditional to complex, personal criteria, not passive as the deficit model suggests.

Third, the deficit model incorrectly assumes that increasing the availability of scientific information to the public and therefore their uptake of the information, would lead to an automatic increase in support for management decisions (Bodmer, 1985; Evans and Durant, 1995; Burns et al., 2003; Fisher et al., 2005; Sanderson et al., 2005). This assumption is highly centralised, and not in keeping with the EBFM ideal of better engagement with resource users and collaborative resource management, and also assumes that only the managers' reasoning and logic are valid. A British study demonstrated that more knowledgeable individuals can be more critical of science, and not necessarily more accepting of new information or more amenable to the cause it supports (Evans and Durant, 1995). That study dealt with science in general and warned that its findings were not necessarily applicable to specific science disciplines (Evans and Durant, 1995). This warning is particularly valid in the case of fisheries science. In a fisheries context, the scientific information being communicated is from a limited number of disciplines, and often presented as 'fisheries science'. Fishers also have a vested interest in the information. However, as no one has tested whether fishers do become more critical of new information as their scientific literacy increases, the effect cannot be ruled out. The inability to cater for the influence of scientific literacy on the uptake of scientific information is a major flaw of the deficit model.

The deficit model's shortcomings for communicating scientific information in a fisheries context become increasingly obvious as the understanding of fisheries stakeholders improves. The uptake of scientific information in the fisheries system is too complex for the application of the deficit model. A comprehensive model applicable to multiple fisheries needs to allow for variables such as cultural, social and cognitive differences between stakeholders and communities.

3.2.2 Development of a new model for the communication of scientific information in a fisheries context

Current thinking is that the uptake of scientific information through informal learning in a fisheries context is more complex than the deficit model suggests, although a consensus on a widely applicable alternative model is yet to be reached (Jacobson and Robinson, 1990; Janssen and Goldsworthy, 1996; Hisschemöller and Midden, 1999; Fisher et al., 2005; Ruth et al., 2005; Sanderson et al., 2005; Critchley, 2008; Frank et al., 2009; Sturgis et al., 2010). Most research directed at understanding public engagement and the relationship between scientific information and the public's perceptions of science is still exploratory at this point, although its importance cannot be overstated. An important consideration for a model for communicating scientific information in a fisheries context is that it should also cater for managers and researchers.

Investigations into potential variables for an alternative model have already begun (Shrigley et al., 1988; Wynne, 1992; Wynne, 1993; Weeks and Packard, 1997; Alsop, 1999; Hisschemöller and Midden, 1999; Nisbet et al., 2002; Degnbol, 2005; Gerhards and Schäfer, 2009). The new model needs to incorporate several variables including individuals' scientific literacy, their existing perceptions of the source and nature of the new information, the suitability of the information's format, the amount of power they hold in fisheries management, their ability to make sense of the new information, whether they consider the information useful, the new information's compatibility with their cultural or social background, their past experiences with similar information and sources, their interest in the new information, and if the new model is to be applied to stakeholder groups, a social component (e.g. Social constraints placed on individuals, social incentives to uptake the information etc.) (Shrigley et al., 1988; Wynne, 1993; Ehrlich and Ehrlich, 1996; Weeks and Packard, 1997; Alsop, 1999; Hisschemöller and Midden, 1999; Burns et al., 2003; Eraut, 2004; Degnbol, 2005).

In the following section I outline the development of a new model to guide research into science communication in a fisheries context. The model is based on the idea that learning about fisheries science largely occurs informally (i.e. outside academic contexts). In the model, cognitive, conative and affective variables are conceptualised as having the strongest and most direct effects on informal learning. Other variables, such as scientific literacy, delivery method, and power in fisheries management, are conceptualised as having indirect effects on informal learning and are modelled as being mediated by cognitive, conative, and affective variables. A diagram of the proposed model is presented in Figure 3.1**Error! Reference source not found.**. I discuss each of the variables in the model and their relationships in the sections below.

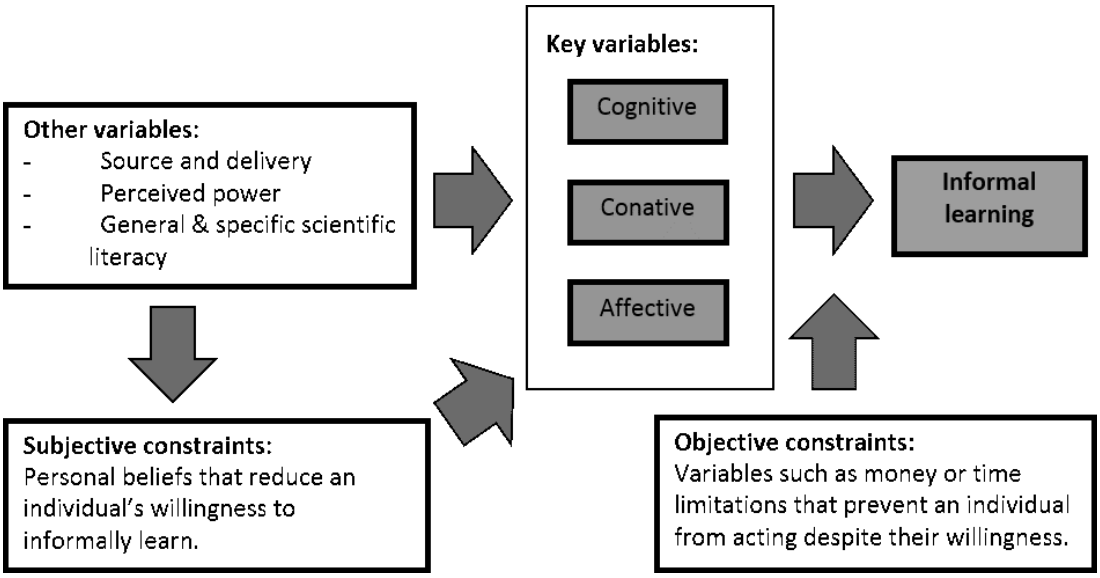

Figure 3.1 Hypothetical model for the uptake/informal learning of scientific information based on existing literature (Posner et al., 1982; Weeks and Packard, 1997; Hisschemöller and Midden, 1999; Degnbol, 2005; Sutton, 2006). The variables listed in the box labelled 'other variables' are considered by the literature to affect informal learning. However, it is likely they act through the cognitive, conative and affective variables forming the basis of this model. The boxes labelled 'subjective constraints' and 'objective constraints' describe variables that inhibit an individual's willingness or ability to informally learn respectively, although they act at different stages in the model (Sutton and Tobin, 2011).

3.3 Informal learning

Informal learning is conceptualised as being the independent variable in the model. Informal learning is not a new concept; however, its application to the fisheries context is relatively recent.

In the fisheries context, the uptake of new information is largely through informal learning. Fisheries science is not taught in a formal, academic environment to the majority of fisheries stakeholders. Because of its applicability to scientific information in the fisheries management context, informal learning will form the basis of the new model described below.

Unlike formal learning that occurs in a formal academic environment with the assistance of an individual who considers themselves to be an educator, informal learning occurs outside a formal academic environment (Schugurensky, 2000). A more knowledgeable individual can pass the information on, but they cannot consider themselves a formal educator (Alsop, 1999; Schugurensky, 2000). Unlike formal learning, informal learning is unassessed, and there are no formal consequences or penalties for not taking up the new information in informal learning environments (Alsop, 1999).

Schugurensky (2000) describes three varieties of informal learning: 1) self-directed learning that occurs intentionally where the decision to learn is conscious and the individual is aware that they have learned something; 2) incidental learning where the learner did not have a previous intention to learn but is aware of having learned something afterwards; and 3) socialisation, which occurs tacitly without the individual being aware of having learned something afterwards. Because incidental learning and socialisation are difficult to incite, most efforts to encourage the uptake of fisheries science are designed to appeal to self-directed learning with the hope that incidental learning and socialisation will occur afterwards.

Informal learning occurs every day, and affects all fisheries stakeholders. Managers and researchers do practise informal learning in the fisheries management context. While managers and researchers acquire most of their earlier knowledge in a formal, academic environment, much of their more complex and advanced knowledge is acquired as part of their job (Cvitanovic et al., 2014). Managers and researchers acquire much of their knowledge through reading scientific papers, attending conferences and meetings, networking and conducting research (Cvitanovic et al., 2014). Because this learning is not conducted under a strict, pedagogical framework, it is not considered formal learning i.e. the learning is mostly voluntary, not assessed in the formal sense, or taught by an individual who considers themselves an educator (Alsop, 1999; Schugurensky, 2000). While the atmosphere in which managers and researchers learn informally is more rigid than what might be expected for fishers, this learning is still considered to be informal. How managers and researchers arrive at the decision to informally learn in fisheries management and uptake multidisciplinary data is important information if the conflicts between natural and social scientists are to be resolved (Bauer, 1992; Touval and Dietz, 1994; Berkenkotter and Huckin, 1995; Endter-Wada et al., 1998). Understanding the variables controlling managers' and researchers' informal learning might also offer insight into how best to maximise fishers' informal learning.

Fishers have not traditionally had easy access to most fisheries-relevant scientific information. Therefore, understanding fishers' reactions to a deliberately increased exposure to scientific information as a result of decentralised management regimes is important for successful communication and engagement between stakeholders and fisheries management (Burkardt et al., 1998; Burger et al., 2001). Fishers' reactions could range from violently negative to co-operatively positive and anywhere between depending on the context, format and timing of the information's delivery (Wynne, 1993). The decision to uptake scientific information is also made on the individual level according to several variables that will be discussed later in this section. There is also a social component to informal learning. Informal learning can be affected by the fisher community's level of scientific literacy as well as the culture and the structure of that community. Scientific literacy, cultural compatibility and community hierarchy are liable to affect fishers' willingness and reactions to the uptake of scientific information (Wynne, 1992; Schusler et al., 2003). How social learning affects the uptake of scientific information will be discussed later.

3.3.1 The cognitive, conative and affective variables

Variations of the cognitive, conative and affective variables have been identified as being important in the uptake and acceptance of scientific information and this justifies their presence at the core of the model [Figure 3.1] (Posner et al., 1982; Weeks and Packard, 1997; Hisschemöller and Midden, 1999; Degnbol, 2005; Sutton, 2006; Sarkki et al., 2013, 2015). These three variables were originally explicitly defined in attitude research and were adapted to describe attitude in formal learning environments by Shrigley et al. (1988) before being incorporated into Alsop's proposed Informal Conceptual Change Model (ICCM) (Shrigley et al., 1988; Alsop, 1999).

The cognitive variable describes whether the new information is compatible with an individual's sense of logic, or is an improvement on his/her previous beliefs and whether he/she can apply the new information consistently in a useful or meaningful manner; i.e. Does the information make sense? Can that information be used later on? (Posner et al., 1982; Alsop, 1999). Problems can arise when managers and fishers have incompatible senses of logic. For example, several international studies have noted conflict to occur between fishers and managers when fisheries management zones were proposed that were configured using criteria fishers did not agree with (Clay, 1993; Degnbol, 2005). Fishers saw a geographical limitation to their fishing activity while managers perceived an area that not only preserved biodiversity, but also allowed the replenishment of local fish stocks through dispersal. Fishers agreed with the need to preserve their local fisheries and regulate their catch, but objected normatively because the logic behind protected areas in the ocean did not agree with their own reasoning (Clay, 1993; Degnbol, 2005).

The affective variable describes the role of emotion, and involves how an individual feels about the new information and whether there is an external influence e.g. their peer groups (Alsop, 1999). Positive affect has been linked with increased motivation, clearer thinking and increased thoughtfulness, which is likely to have positive implications for the cognitive and conative variables included in the hypothetical model for informal learning [Figure 3.1] (Isen, 2001). In Rockhampton, in the Great Barrier Reef region of Australia, recreational fishers were enthusiastic about partaking in the collection of scientific information relevant to fisheries management (Li et al., 2010). An enthusiastic stakeholder group with a positive attitude towards scientific information is an ideal candidate for outreach from management agencies.

The conative variable describes whether the new information meets the individual's everyday needs: i.e. does the information mesh with an individual's daily routines and objectives? (Alsop, 1999). A fisher, for example, is unlikely to find a regular use for knowledge regarding the endocrinology of sharks. They are, therefore, less likely to uptake that information as opposed to the size at maturity (which affects the size they are able to be harvested) of their favourite target species. Previous research suggested that recreational fishers drew relevance between an improved knowledge of fisheries science and their abilities to improve their fishing and make their activities more environmentally friendly (Li et al., 2010). The "relevance" of a piece of scientific information has also been directly attributed to how successfully that piece of information is incorporated into policy on the science-policy interface (McNie, 2007; Sarkki et al., 2013, 2015). It is therefore reasonable to assume that a perceived usefulness (i.e. the conative variable) of the new information might be important in informal learning among fisheries stakeholders. The appearance of variations of the cognitive, conative and affective variables in literature about the uptake and acceptance of scientific information/principles and their broad applicability make these three variables a good base for a general model for an individual's uptake of scientific information.

3.3.2 Scientific literacy

Scientific literacy is conceptualised as having a strong effect on an individual's response to scientific information by directly influencing an individual's cognitive, conative and affective responses to scientific information. Scientific illiteracy among the public has long been considered a problem that needs to be resolved before the goal of a more knowledgeable public can be attained (Ehrlich and Ehrlich, 1996; Dawkins, 1998; Miller, 2001). Being scientifically illiterate limits an individual's ability to cognitively access scientific information. Being unable to cognitively access information limits an individual's ability to apply it to everyday tasks or objectives: i.e. scientific literacy can affect the conative variable. Scientific literacy or lack thereof also has an affective component, as demonstrated by Evans and Durant's 1995 study. Increasing individuals' levels of scientific literacy alone is unlikely to automatically improve their attitude regarding science (Evans and Durant, 1995). Although their findings are not necessarily applicable to the fisheries context, the study by Evans and Durant (1995) demonstrated that a scientifically literate individual can assess new information differently than one who is less scientifically literate. Since scientific literacy can affect an individual's ability to make sense of new scientific information, and find a use for it, it is an important variable to consider in the construction of a new model for informal learning in a fisheries context.

3.3.3 Power and leverage

The amount of power or leverage individuals have (e.g. political power, money, moral arguments etc.) in fisheries management is also likely to influence their willingness to uptake new information (Weeks and Packard, 1997). The placement of 'power and leverage' in the model [Figure 3.1] is because individuals' power and leverage contextualises their placement in fisheries management and therefore what they may or may not find useful or relevant. This variable also affects the cognitive, conative and affective variables. An individual with more power in a fisheries management environment is often more privy to and therefore more familiar with fisheries science in its original format, hence the cognitive affect. An individual who feels they have more power in decision making processes is also more likely to uptake and use scientific information than an individual who feels they have little or no power in the process; this is the affective effect. Researchers or managers with power in the fisheries management environment might find a piece of scientific information more relevant to their daily activities than a fisher who has little to do with the research or managerial environment, hence the conative affect. While a high level of power might be assumed in the case of fisheries managers, this consideration is still important for other stakeholders, particularly as the level of power assigned to fishers varies from fishery to fishery and as fishers gain increasing power through co-management and other forms of meaningful engagement.

3.3.4 Source and delivery: Relationships with scientific information

In the model [Figure 3.1], the variable 'source and delivery' is where direct and indirect potential interactions with other variables first branch out. 'Source and delivery' appears at this position in the model because this is when an individual first becomes aware of the new information. The source and delivery of new scientific information feeds into the 'scientific literacy' and 'power in fisheries management' variables but can also directly affect the three cognitive, conative and affective variables. This variable is also the easiest to control and change.

The source of the new information has a larger affective component. Negative relationships or experiences with stakeholders have been shown to hamper collaboration efforts at a later date (Clay, 1993). Stakeholders are less likely to trust a source that they have had a negative experience with. However, positive relationships between stakeholders and the source of the information also enhance uptake (Weeks and Packard, 1997). Stakeholders' perceptions of the information source can also be affected more subtly. For example, the public's opinion about a certain field of research and its application can be compromised by the perception that there is a lack of consensus among scientists or agencies (Wynne, 1993; Cunningham et al., 1994; Hisschemöller and Midden, 1999).

The information's format is no less important than its source. The format has the capacity to affect all three of the core variables in the model [Figure 3.1]; i.e. cognitive, conative, affective. Fishers may have different opinions regarding a piece of information depending on whether it is published in a well-known fishing magazine as opposed to a peer-reviewed scientific paper or a leaflet from a management agency. Fisheries managers might have different opinions again depending on how the information is presented. In both these instances, the affective variable is involved. Further, if the information is presented in a format that is incomprehensible or unfamiliar to stakeholders, it becomes difficult to cognitively access i.e. the cognitive affect. Similarly, an inability to cognitively access the information limits the ability of stakeholders to see a use for the new information i.e. the conative affect. If the information fails to appeal cognitively, affectively or conatively, it is unlikely to warrant further consideration, and uptake becomes unlikely. Both the source and method of delivery of the information are important variables to be considered in a new model of informal learning in a fisheries context.

3.3.5 Constraints

Informal learning can be conceptualised as a series of behaviours culminating in the uptake of new information. Individuals engage with and contextualise the information on a multitude of levels (e.g. cognitively, conatively and affectively) before finally deciding whether to uptake the information. It is therefore possible for constraints to come into play at any point during the informal learning process. This thesis' focus is on understanding informal learning in the fisheries context. Specifically, this thesis is about examining the informal learning of scientific fisheries information that can inform environmental behaviour (e.g. engagement in management decision making processes, consultations etc.). The ipsative theory of behaviour describes three kinds of constraints to behaviour (Tanner, 1999):

- Ipsative constraints affect the activation of a behaviour (Tanner, 1999). In the context of this thesis, and the informal learning of scientific fisheries information, ipsative constraints would prevent the target audiences from becoming aware of a piece of scientific information (e.g. physical accessibility).

- Subjective constraints affect the desire to act (Tanner, 1999). These constraints generally affect behaviours before opportunities to act upon them arise, hence their placement in the hypothetical model [Figure 3.1] (Sutton and Tobin, 2011). Subjective constraints are based on individual choice and the individual's beliefs about what is possible, allowed or pleasurable (Tanner, 1999). Naturally, these constraints also have a strong cultural context, and it is possible that they might differ between fisheries stakeholders (Tanner, 1999). For example, fisheries stakeholders' perceived levels of power in management decision making might become a subjective constraint, should they feel it is beyond their ability or responsibility to engage with and therefore uptake the new information. A lack of cognitive access to a new piece of information could also be considered a subjective constraint to informal learning. If stakeholders find information difficult to understand/engage with, they could then become less willing to uptake it (Shrigley et al., 1988; Alsop, 1999).

- Objective constraints are those that directly affect the ability to carry out the behaviour despite their intentions (Tanner, 1999; Sutton and Tobin, 2011). Objective constraints prevent individuals from acting despite their willingness and ability to do so otherwise, hence their placement in the hypothetical model [Figure 3.1] (Tanner, 1999; Sutton and Tobin, 2011). Limited resources such as money or time might be considered objective constraints (Tanner, 1999; Sutton and Tobin, 2011). Among fisheries stakeholders, these constraints are also likely to be slightly different as fisheries researchers have free access to many of the resources that commercial and recreational fishers would need to pay for. Cognitive and physical accessibility might also come into play for both recreational and commercial fishers. Owing to their different contexts and responsibilities within fisheries, managers, researchers and commercial and recreational fishers are also likely to have different perceptions of how much time they need to spend informally learning fisheries science. Fisheries managers and researchers must keep their knowledge of the resource and its management current. Therefore, informal learning of scientific fisheries information is a big part of their occupation. For commercial and recreational anglers, informal learning of scientific fisheries information is largely voluntary and must occur outside of their usual working hours.

3.4 Variables external to the model

The following variables were not included in the model [Figure 3.1] because of their complex and wide-ranging effects on informal learning. These two variables are also correspondingly difficult to measure. Personal objectives are often multi-dimensional, and situation-specific. Social learning also affects several of the variables included in the model [Figure 3.1] as well as including more complicated issues such as controlling individuals that can inhibit the actions of community members after informal learning has occurred. The model [Figure 3.1] caters for some of the effects of both personal objectives and social learning, but does not capture the full complexity of either. Both of these external variables are discussed in detail below.

3.4.1 Personal objectives

Personal objectives are not included in the model [Figure 3.1] because they are ill-defined and encompass a number of the variables included in the model. All fisheries stakeholders (managers, researchers and fishers) have a complex, and existing, set of personal objectives (van Riper et al., 2012). If individuals reason that new scientific knowledge conflicts with their personal objectives, they may prefer to remain ignorant of the science (Wynne, 1993). For example, a fish biologist might disregard a new paper about the social hierarchy in fishing communities if he or she did not consider it to be useful for career advancement. Similarly, a commercial or recreational fisher might dismiss a paper about fish biology because the information does not appear immediately useful to his or her fishing activities. The ignorance is not due to neglect or unwillingness to learn, but is reasoned, and deemed an appropriate response (Wynne, 1993). The alignment of scientific information with individuals' political agendas, motivations and priorities have also been shown to effect information uptake in a science-policy context (van den Hove, 2007). In some instances, the reasoning behind scientific ignorance is quite complex. For example, workers in a nuclear plant in the United Kingdom chose to ignore the science behind the reactor because they felt that being more conscious of it would make them more nervous, creating a hazardous work environment (Wynne, 1993). Individuals' personal/professional objectives are capable of affecting their attitudes towards a certain field of science. An added danger is that misunderstandings caused by the new scientific information's incompatibility with one individual's morals, personal objectives or reasoning could spread throughout the community (Wynne, 1992). A new, more comprehensive model for informal learning in fisheries management needs to cater for the effect that personal objectives have on an individual's willingness to uptake new fisheries science.

3.4.2 Social learning

Social learning is not included in this model because individual learning occurs within social learning, and social learning is variable and hard to measure. This model [Figure 3.1] attempts to cater for the effects of social learning on individual learning. Social learning dictates how a community learns as a whole and is essential for understanding the uncertainty and complexity in natural resource management (Schusler et al., 2003). Social learning does not occur without individual learning being an option, just as individual learning is unlikely to occur without social learning on a politicised and controversial subject such as fisheries science. Therefore, understanding the variables controlling individual learning is no less important than understanding those controlling social learning in fisheries management.

From a management perspective, understanding social learning is important for stakeholder engagement. Social learning can increase a community's social capital, giving community members greater access to resources available through, derived from and embedded within their existing social networks (Nahapiet and Ghoshal, 1998). However, because social learning occurs at the community level, certain circumstances can cause communities to behave unsustainably despite many community members being well informed and having a good understanding of the issues surrounding their natural resource and its management (Gooch and Rigano, 2010). Individuals are often subject to social pressures within their community, and their learning of fisheries science or engagement with management agencies can be inhibited if powerful members of their community disapprove of these actions (Gooch and Rigano, 2010). Social learning is the link between individual learning and positive engagement with a representative portion of the community. It is in management agencies' best interests to understand and describe the variables that control social learning so that a workable model can be constructed.

However, there are complications associated with applying a social learning model to the communication of scientific fisheries information. It would be unwise to assume fishers, managers and researchers were separate communities without conducting exploratory research. Fishers, managers and researchers are not mutually exclusive. Any person with an interest in fishing is a fisher, including managers and researchers who fish for recreation. Managers can also be researchers, and often have a research background (Endter-Wada et al., 1998). While an individual can identify with one particular role more strongly, the degree to which this occurs might vary from fishery to fishery or issue to issue. Depending on the fishery or issue, it might be more appropriate to treat managers, researchers and fishers as part of a 'fisheries management community' as opposed to discrete communities playing different roles in fisheries management.

A flawed social learning model might lead to serious, negative repercussions. Ineffective social learning can cause incorrect information to spread through the community; creating conflict, or worse, a misguided use of increased social capital (Gooch and Rigano, 2010). Increasing social capital without understanding and addressing a community's attitudes and behaviours towards a resource could encourage unsustainable attitudes and behaviour (Gooch and Rigano, 2010). For example, fish populations might still decline if spawning closures did not allow for less informed fishers intensifying their efforts to harvest more fish immediately prior to and after a spawning closure.

Effective social learning combined with increasing social capital can help communities manage their resources more effectively and become more resilient to change (Schusler et al., 2003; Gooch and Rigano, 2010). Variables that control social learning in a natural resource management context include: the feasibility of participation, mutually agreed upon limitations of authority and responsibilities and a climate of trust and openness (Bouwen and Taillieu, 2004). Owing to the complexity of social learning, these variables might form a good basis for the creation of a social learning model to which to attach an individual uptake model until further key variables affecting social learning are identified.

3.4.3 Summary

Personal objectives and social learning variables are important for understanding how fisheries stakeholders uptake and informally learn fisheries science. However, personal objectives are hard to capture with simple models, and are likely to be location and community specific. Social learning is a complex issue, and the variables controlling it are likely to require a separate model to do them justice. While the model proposed in Figure 3.1 was constructed to describe individual informal learning based on existing literature, the use of the cognitive, conative and affective variables do allow it to capture some of the effects of personal objectives and social learning.

3.5 Conclusion

The widespread adoption of active-adaptive EBFM is a relatively new phenomenon, requiring a change in the way fisheries science and the communication of its outputs are approached. Chapter Two reviewed issues surrounding science communication in a modern fisheries management context, and developed a theoretical model of how scientific information could be communicated and learned in an informal context. However, research into the individual and social learning of fisheries science is not extensive, and few of the studies on the nature of informal learning and the uptake of scientific information have been applied to a highly politicised context involving stakeholders with vastly different scientific backgrounds. Consequently, the model presented in this chapter remains highly theoretical, requiring extensive testing and refinement. The next chapter will begin the process of testing and refining the list of variables discussed in this chapter, and a simplified version of the hypothetical model presented in Figure 3.1.

4. Identifying variables influencing fisheries stakeholders' informal learning of scientific information

Chapters Two and Three set the context and conceptual framework for this thesis. Chapter Two discussed how recent changes to the way fisheries are managed and conceptualised have changed the way scientific information travels between stakeholders. Chapter Three described variables and frameworks that have been related to the communication of scientific information to audiences with diverse scientific backgrounds. This chapter builds upon these previous chapters by testing the applicability of variables identified in Chapter Three to the modelling of how fisheries stakeholders with a diverse range of scientific backgrounds informally learn their scientific information.

The theoretical model used to guide interview design in this chapter is a simplified, and slightly more generalised, version of that presented in Chapter Three. This is because this chapter is a largely exploratory study, and the variables presented in the hypothetical model in Chapter Three have not been studied in sufficient depth with relevance to fisheries stakeholders to take a more reductionist approach.

Thematic analysis was employed to look for drivers of and constraints to informal learning in data gathered using the semi-structured interviews. Fisheries managers, scientists, and recreational and commercial fishers whose activities were based in the Great Barrier Reef Marine Park region were interviewed. Strong evidence was found for the applicability of driving variables from the literature, such as the cognitive, conative and affective dimensions. Evidence of constraints in the form of investments in money and time was also found. New patterns where variables overlapped or interacted differently for different stakeholders were also identified.

This chapter has been written as a stand-alone paper intended for submission to *Rural Sociology* with minor revisions. Therefore, there is some duplication of material presented previously, particularly in the literature review.

4.1 Introduction

The modern active-adaptive approach to natural resource management demands high levels of stakeholder engagement (Bouwen and Taillieu, 2004; Granek et al., 2008; Gray and Jordan, 2010). High levels of engagement are dependent on excellent communication, both between and within stakeholder groups with diverse educational, scientific and knowledge backgrounds (e.g. managers, scientists, commercial and recreational fishers) (Jennings and Moore, 2000). Moreover, as fisheries come under greater pressure, changes to fisheries management are likely to occur with increased frequency, placing greater onus on fisheries management to engage and communicate more effectively with fisheries stakeholders. However, efforts to facilitate the communication of scientific information between and within fisheries stakeholder groups have not been based on a theoretical understanding of stakeholders' engagement and communication needs (Chapters 2, 3). Consequently, little is known about which variables might improve or hamper fisheries stakeholders' interest in learning a new piece of scientific fisheries information.

Understanding the variables affecting the way fisheries stakeholders engage with, assess and uptake scientific information has potential to be highly beneficial for constructing communication strategies aimed at fisheries stakeholders. A strategy based on communication theory and variables affecting fisheries stakeholders' uptake of scientific information could be applied to any medium. This flexibility is becoming increasingly important as the digital age and the prolific adoption of social media has increased the speed at which people communicate, and also how quickly they can change their communication preferences. Communication strategies focused on the use of specific media will find it increasingly difficult to keep pace with stakeholders' communication needs and habits into the future. Therefore, a theory-based model is likely to be more flexible and potentially have greater longevity than one based on specific communication platforms.

One comparably well researched concept that could be generalised to modelling the uptake of scientific information among fisheries stakeholders is informal learning (Chapter 3). All fisheries stakeholders uptake at least some of their scientific information through informal learning. Managers and scientists acquire most of their current knowledge through informal learning despite having gained their early knowledge through tertiary schooling. Commercial and recreational fishers also acquire most of their current scientific information through informal learning. The concept of informal learning and its applicability is described in more detail in the following literature review. Chapter Three proposed a hypothetical model for informal learning by fisheries stakeholders based on existing literature about informal learning, public understanding of science, and the uptake of scientific information by fisheries stakeholders. The aim of this chapter is to build upon Chapter Three by using a simplified version of the hypothetical model as a guideline for seeking and validating tangible and discrete variables that could be used to model informal learning by fisheries stakeholders and ultimately, to understand how the communication of scientific information to and between fisheries stakeholders can be improved into the future.

4.2 Developing a generalised, testable model of informal learning

Variables used to describe the informal learning of scientific information by fisheries stakeholders with diverse scientific backgrounds must be flexible without being too general. The flexibility is necessary to encompass the various fisheries stakeholders' perceptions and conceptions of the fishery, and therefore, how it should be managed. The stakeholders included in this study are the major actors in fisheries management systems: fisheries managers, scientists and commercial and recreational fishers. Each of these fisheries stakeholder groups have vastly different roles in the fisheries management system, and therefore, relate to new scientific information in a different way (Pomeroy and Berkes, 1997; Jacobson and McDuff, 1998). Their different levels of scientific training will also affect stakeholders' conceptions of fisheries systems, and therefore, the way they contextualise new information (Clay and Goodwin, 1995; Ludwig, 2001; Cvitanovic et al., 2014). Informal learning and public understanding of science literature contain a few variables and concepts that are discrete enough to be useful, but flexible enough to encompass a wide range of conceptions and attitudes.

The concept of informal learning is well studied, and has the potential to be applied to fisheries stakeholders. Informal learning occurs outside of formal, institutionalised environments. There are no regular assessments, trained educators or formal consequences for not learning the information (Alsop, 1999; Schugurensky, 2000). Informal learning is how most adults learn new information, encompassing learning through social interactions and corporate communication. Informal learning is therefore a potentially useful tool for understanding the uptake of scientific information among fisheries stakeholders. In general, fisheries managers and scientists are formally educated on fisheries science or related fields at a tertiary and post-graduate level, but much of their knowledge is acquired informally while 'on the job' through meetings, conversations and sharing and reading resources. Commercial and recreational fishers also informally learn scientific fisheries information, though the context in which they do so is quite different than that of fisheries managers and scientists. Therefore, while the concept of informal learning is applicable to all fisheries stakeholders, the variables controlling their informal learning might vary substantially.

One model from the informal learning literature identifies three key controlling variables. This model is Alsop's Informal Conceptual Change Model (ICCM), and includes three key dimensions: The cognitive, conative and affective dimensions (Alsop, 1999). The definitions of the three dimensions forming Alsop's ICCM are as follows:

- The cognitive dimension describes how well a new piece of information fits in with an individual's existing knowledge, or conception of a system and whether the individual could conceive a potential use for the information.
- The conative dimension describes how regularly useful a piece of information appears to an individual.
- The affective dimension describes any emotions the individual might associate with the new information, including the way the information is presented, the person/source presenting the information, the implications of that information etc.

Many other studies seeking to model or identify variables controlling the informal learning of scientific information describe variables similar to those described by Alsop. General and specific scientific literacy have been correlated with individuals' abilities to cognitively engage with new scientific information and affect the way they uptake that new information (Bodmer, 1985; Aikenhead, 1989; Bauer, 1992; Evans and Durant, 1995; Dawkins, 1998; Fensham and Harlen, 1999). In fisheries, there have been examples where fishers' local knowledge conflicted with the scientific information being presented to them, resulting in conflict regarding changes to the management of their fishery (Clay, 1993).

How immediately relevant, or useful, a piece of scientific information appears to an individual has also been correlated with different rates of uptake among individuals (Fensham and Harlen, 1999; Osborne et al., 2003). Increased relevance has been associated with an improved uptake of scientific information in students in formal environments, as well as members of the public (Alsop, 1999; Fensham and Harlen, 1999; Osborne et al., 2003). A lack of perceived relevance has also been found to hamper the uptake of scientific information among stakeholders with greater power in natural resource management systems, and those working on the science-policy interface such as conservation planners/managers, scientists and policy-makers (McNie, 2007; Cvitanovic et al., 2014).

The affective, or emotional, dimension has also been shown to directly affect individuals' abilities to solve problems, think laterally, and engage with the new information in an organised manner (Isen, 2001). A positive emotional state has been shown to enhance individuals' abilities to think laterally/expansively (i.e. potentially identify more uses for a new piece of information), engage with new information with greater clarity, and to think more deeply on a subject (Isen, 2001). As people's livelihoods and lifestyles are tightly bound with fisheries and their use, management changes that affect/limit this use and the associated messaging can be expected to generate some emotional response. Therefore, any informal learning model illustrating the informal learning of scientific information among fisheries stakeholders should certainly include the affective dimension. The fact that multiple independent studies corroborate the variables used in Alsop's ICCM indicate that these are likely to form a good foundation for further investigations into the informal learning of scientific fisheries information in fisheries stakeholders.

Stakeholders' informal learning of scientific information can also be constrained by some variables (Chapter 3). Variables likely to constrain informal learning are also described in the literature and are no less important. These constraining variables include the negative equivalent of some of the above mentioned variables (Tanner, 1999; Sutton and Tobin, 2011). For example, a lack of agreement with individuals' existing knowledge, a lack of perceived regular usefulness and the association of negative emotions with the new information/messaging are likely to constrain stakeholders' informal learning of scientific information (Clay, 1993; Alsop, 1999; Isen, 2001; Osborne et al., 2003; Vanclay, 2004). These three examples are what the literature describes as 'subjective' constraints (i.e. constraints based on an individual's beliefs), hampering an individual's willingness to act (Tanner, 1999). Other variables likely to act as constraints on fisheries stakeholders' informal learning of scientific information include investments in time and money (Tanner, 1999; Sutton and Tobin, 2011). These variables are considered 'objective' because they constrain individuals' behaviour independently of their willingness to act i.e. these variables can constrain stakeholders' willingness to uptake new scientific information even if they subjectively wish to do so (Tanner, 1999; Sutton and Tobin, 2011). Understanding the distinction between the two kinds of constraints is important for the correct placement of these constraints in a model of fisheries stakeholders' informal learning, and to guide the lines of questioning in studies investigating these constraints.

The literature does not address whether fisheries stakeholders might have unique or undiscovered variables controlling their informal learning of scientific information [Figure 4.1]. So far, little informal learning research has been focused on natural resource stakeholders. In a system like fisheries management, all stakeholders have vested interests in the resource persisting into the future and in ensuring that the benefits of the resource's use reach society at large. Moreover, in fisheries, the resource users must abide by science-based regulations and recreational fishers in particular have expressed an interest in the science behind these regulations (Li et al., 2010).

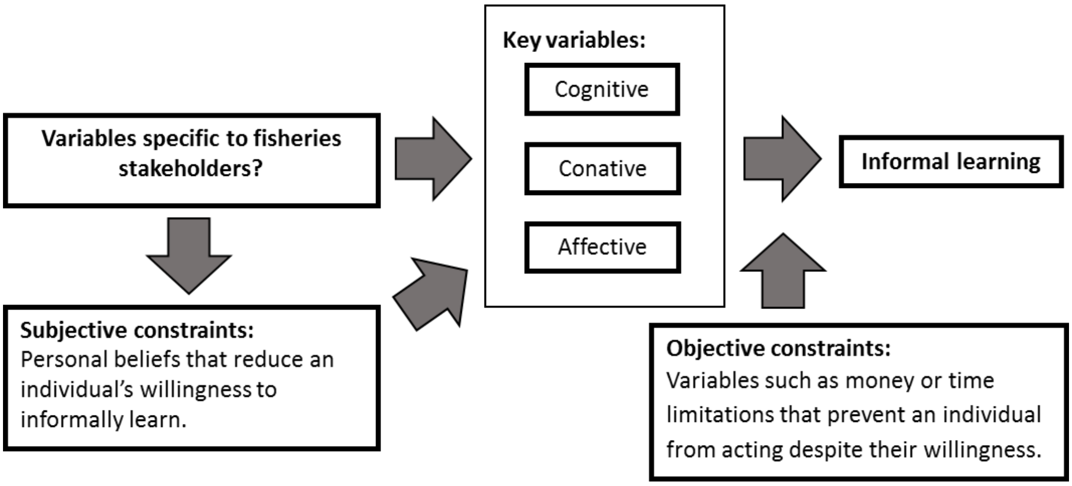

Figure 4.1 Generalised hypothetical model of fisheries stakeholders' informal learning derived from the current literature. (NB: This model is a slightly simplified version of that presented in Chapter Three, as explained in the caption at the beginning of this chapter).

The literature presented here and in Chapter Three forms the basis of this study's explorations into understanding and identifying the variables influencing informal learning in fisheries stakeholders. To improve the likelihood of identifying variables not included in the literature, semi-structured interviews were employed to tease out variables that may be specific to controlling informal learning in fisheries managers, scientists and commercial and recreational fishers.

Aim: To identify variables facilitating and constraining the informal learning of scientific fisheries information in fisheries stakeholders from a range of backgrounds.

Research questions:

1. How applicable is the concept of informal learning to understanding how fisheries stakeholders take up and use scientific information?

2. How applicable are the cognitive, conative and affective dimensions of informal learning to fisheries stakeholders' uptake of scientific information?

3. Are there any variables influencing fisheries stakeholders' informal learning of scientific information that are yet to be identified in the literature?

4. What variables are likely to constrain fisheries stakeholders' informal learning of scientific information?

4.3 Methods

4.3.1 Study site and population

This study was undertaken in the Great Barrier Reef (GBR) region in North Queensland, Australia. The sample for this study included 29 fisheries stakeholders with different relationships and roles in the fisheries management system (i.e. managers, scientists, commercial fishers, and recreational fishers) [Table 4.1]. For the purposes of this study, fisheries stakeholders were grouped according to their primary roles in the fisheries management system only.

Snowball sampling was used to select the interviewees. Most of the fisheries stakeholders interviewed lived in the area adjacent to the Great Barrier Reef Marine Park (GBRMP), and were interviewed on an individual basis, either in person or using the telephone. Several managers and scientists did not reside in the area, although their study sites or jurisdictions did include the GBR region. These managers and scientists were also interviewed in person where possible, and using the telephone when that was the only option.

Table 4.1 Breakdown of the sample by stakeholders' primary role in the fisheries management system. GBRMPA – Great Barrier Reef Marine Park Authority; DAFF – Department of Agriculture, Fisheries and Forestry; CSIRO – Commonwealth Scientific and Industrial Research Organisation.

Stakeholder group	Agencies/sectors represented	Number
Managers	GBRMPA, DAFF	8
Scientists	DAFF, CSIRO	9
Commercial fishers	Northern prawn trawl, Spanish mackerel fishery, coral reef fin fish fishery	5
Recreational fishers	NA	7

Interviews were arranged for a time most convenient for the respondents, and each interview was voice recorded for transcription later. Once the interviews were transcribed, they were encoded using NVivo 10 software into nodes corresponding to variables identified in the literature; any that did not clearly fit into pre-existing variables were allocated new nodes. Approval for this research was granted by the James Cook University Human Research Ethics Committee (Ethics application number: H4079), and all interviewees were asked to sign an informed consent form before the commencement of the research activity.

4.3.2 Interview design

The interview design was semi-structured and qualitative. The structured elements of this survey were designed to identify the presence of variables from the literature [Appendix B]. They consisted of open-ended questions about explicit, individual variables from the hypothetical model (i.e. the cognitive, conative and affective dimensions, effects of time and monetary investments, emotional associations with the information). Interviewees were also asked open-ended questions about their past informal learning practices/experiences. For example, interviewees were asked to recall instances where they felt scientific information was presented well to them, as well as an instance where they felt it was presented poorly, and to elaborate upon these experiences (i.e. what they felt made it a poor/good presentation of scientific information). The following is a more detailed, section by section description of the interview design.

4.3.2.1 Applicability of the concept of informal learning

The primary objective of this chapter was to test the applicability of informal learning and the variables driving it to fisheries stakeholders, and their uptake of scientific information. Data concerning the uptake of scientific information by fisheries stakeholders were gathered using questions about pieces of scientific information that were requisite common knowledge for each stakeholder group, and which most stakeholders would not have been exposed to in a formal education context.

Fisheries managers and scientists were questioned about marine parks, the rationale behind the different zones within the GBRMP, and also the zoning practices used during the implementation of the 2004 Zoning Plan (Great Barrier Reef Marine Park Authority, 2004). While knowledge of the principles behind the placement of marine parks and their use are not requisite knowledge for all fisheries managers and scientists, it is generally expected that they have the knowledge. The concept of marine parks has been taught formally for decades. However, the marine parks as they currently exist in the GBR region were only implemented on a large-scale relatively recently, in 2004 (Great Barrier Reef Marine Park Authority, 2004). Therefore, managers and researchers alike were unlikely to have been formally educated about the details pertaining to the purpose(s) behind the different zones within the GBRMP, and the practices used to put these zones in place, and were more likely to have learned that information informally. In many instances, the managers and scientists engaged with the information regarding marine parks beyond simply memorising it, and commented on the processes and principles behind installing marine parks.

Commercial and recreational fishers were questioned about the rationale behind bag and size limits for fish. While this information is not usually taught in formal education environments it is readily available, widely publicised, and often used to justify changes made to existing bag and size limits for fish species of interest to fishers.

Other examples of informal learning presented in the results section arose organically during the interviews, and reflect instances where stakeholders volunteered their knowledge with relevance to other lines of questioning.

4.3.2.2 Gaining context

To inform the lines of questioning in the interviews, stakeholders were asked simple questions to gauge where they felt they fit into the fishery. Interviewees were asked how long they had been involved with the fishery in their current capacity/role (i.e. managers were asked how long they had been managers; scientists asked how long they had been fisheries scientists etc.) and whether they related to the fishery outside of their primary role (e.g. whether managers and scientists also fished etc.). Particular attention was paid to interviewees' responses about how important fishing, fisheries related research, or fisheries management were to themselves as individuals. The information gathered here informed questions on how interviewees' existing interests, professional responsibilities, and previous experiences influenced their past informal learning of scientific fisheries information. In part, this section also informed lines of questioning about the importance of the conative (i.e. regular usefulness) dimension to interviewees' informal learning of scientific information.

4.3.2.3 Exploring the importance of the cognitive dimension

This section of the interview was mainly composed of questions aimed at gauging the potential importance of the cognitive dimension in interviewee's informal learning. To do this, two examples of scientific information from two vastly different disciplines were offered to the interviewees. One was based on a study from the natural sciences, and the other on a study from the social sciences [Appendix A]. Most fisheries management decisions in the Great Barrier Reef region have been heavily based on the natural sciences. Therefore, most of the intended interviewees were likely to have been exposed to outputs from the natural sciences and be familiar with them. In contrast, it was unlikely that most of the interviewees would be familiar with outputs from the social sciences. The conflicts that exist due to the differences between the two disciplines have also been well documented in natural resource management around the world (Endter-Wada et al., 1998; Jacobson and McDuff, 1998; Patterson and Williams, 1998; Ewel, 2001).

Interviewees were asked to read both of the short examples of scientific fisheries information [Appendix A] before questioning began. Both of these examples were brief – only one paragraph in length – and written in a journalistic style. Each example contained two or three scientific ideas based on the interpretation of data from the studies they were based on. The studies were chosen based on their relevance to the Great Barrier Reef region and the activities of the target stakeholders. The first example was about the effects that cyclones had on catch rates for two well-known and popular reef finfish species (Tobin et al., 2010). The second example was about recreational fishers' usage of the Great Barrier Reef Marine Park after the amount of area covered by green zones (where fishing is prohibited) was increased from 5 to 33% in 2004 (De Freitas, 2010). In addition, both studies had results that were easily graphically represented and relatively easy to conceptualise: i.e. neither study required an existing knowledge of the dominant theories and concepts in fisheries science to comprehend.

A semi-structured questionnaire was used to guide lines of questioning during the interviews [Appendix B]. The questions that were asked focused on ascertaining whether interviewees had prior experience with information from the natural and social science disciplines, how easy they found the two examples to understand, how useful they might find that information, and whether they drew relevance between the two studies and their own activities, or those of fellow stakeholders and their perceived roles in fisheries.

Interviewees were first questioned about the first example of scientific fisheries information they were asked to read i.e. the study from the natural sciences. This particular study was about two popular target species for both commercial and recreational fishers in the region and the effect of cyclones on their catch rates.

Interviewees were then questioned about the example of scientific information from the discipline of social science. Again, interviewees were asked about their experience with this sort of information, and to draw relevance between the information at hand and their own interests and perceived role in the fishery. If the interviewees felt there were differences between the way they perceived the social science example and the natural science example, they were asked to expand on that and explain why they felt that way.

These two examples were presented to interviewees for two different reasons. The first was to stimulate informal learning in the stakeholders, or remind them of something that they had learned informally. Previous studies have found that putting interviewees in the environments they are being questioned about produces responses with greater resolution, enabling more nuanced and sophisticated analyses (Jones et al., 2014). Since informal learning is such a fluid process, it was deemed more appropriate to put interviewees in an appropriate frame of mind by stimulating informal learning through the presentation of these two examples of scientific studies, rather than attempt to arbitrarily place them in an environment where they had been/would be informally learning.

The second reason was to gauge the effect of the cognitive (and potentially affective) variable through giving the stakeholders an example of scientific fisheries information that they were less familiar with (i.e. the social science example). Because fisheries have historically been managed with a greater emphasis placed upon the natural sciences, and most management tools relevant to resource users are based upon findings from the natural sciences, most fisheries stakeholders are more likely to be familiar with studies from the natural sciences, whereas studies from the social sciences have been known to cause confusion and conflict among even managers and scientists with tertiary science degrees (Clay and Goodwin, 1995; Endter-Wada et al., 1998).

4.3.2.4 Motivations for/constraints to the use of information sources

This component of the survey involved asking interviewees about their experiences with any kind of scientific fisheries information, what they found interesting and what their sources of information were. The goal of these questions was to identify stakeholders' preferred information sources and the variables that might have driven their preference for certain information topics or sources. Interviewees were also asked whether and how they sought fisheries science and which sources they used and trusted. To ensure interviewees were not just listing information sources they knew of but had never used, they were asked what they learned from the first two or three sources they mentioned. Interviewees were not assessed on the accuracy of their recollection since this project is focused on what drives informal learning, and not necessarily the accuracy of their uptake. Finally, interviewees were asked to recall any sources they knew of and simply did not use (i.e. the information source was not deemed untrustworthy) and if there were any sources they did not trust. Interviewees were asked why they did not use the sources that they could recall but did not use and why they did not trust the sources they mentioned as untrustworthy. The last portion of this component was designed to elicit responses that might indicate subjective or objective constraints to stakeholders' informal learning.

4.3.2.5 Past experiences with fisheries science

This component of the survey involved questioning interviewees about their past experiences with scientific fisheries information. The objective here was to detect variables that had actually been important in controlling their informal learning in the past, not to ask interviewees which variables they believed might control their informal learning in a hypothetical context. Interviewees were probed on why they felt a piece of scientific fisheries information was presented very well or poorly and whether their past experiences had any bearing on the way they felt about scientific information from a similar discipline, source, or topic. Finally, interviewees were asked what might influence their ability to trust a new piece of scientific information, or what might lead them to mistrust that information.

4.3.3 Thematic analysis

Passages from the transcribed interviews were sorted using a thematic approach according to their relevance to variables from the literature. Using NVivo 10 software, passages were categorised according to the variables to which they were relevant. None of the variables were considered mutually exclusive (i.e. passages relevant to more than one variable were coded under every relevant variable). After all passages were coded, the passages listed under each variable/category were checked to ensure no passages were mistakenly assigned, or missed. Any variables/categories deemed redundant or lacking in consistency had their passages coded to more appropriate and well defined variables/categories before being deleted. To ensure there was no bias towards more verbose stakeholders, a table was constructed that counted only the presence/absence of a variable in stakeholders' transcripts, and not the number of times one was mentioned. All transcription and coding was done by myself.

The final variables/categories are as follows:

Cognitive

Phrases pertaining to the importance of logic were coded under the cognitive node. It is important to note that the term 'logic' is used here to describe an individual's sense of logic based on his/her own knowledge, experiences and reasoning – not necessarily an adherence to scientific fact. This node was about whether the individual could make sense of a piece of information and perceive a potential usefulness for it. Phrases about how a respondent engaged with and critiqued a piece of scientific information, appraised an information source, or compared new information to their present knowledge were all recorded under this node. Additionally, if a respondent found a piece of information hard to understand, or felt it could be presented in a format that was easier to understand, it was also coded under this node.

Conative

Phrases coded under the conative node reference the perceived regular usefulness of the new information or information that was taken up in the past. If the interviewee mentioned the repeated use of, or intention to repeatedly use, a particular piece of information it was coded under this node. Alternatively, if the interviewee specified that the reason why he or she did not uptake a piece of information was because it was not useful, or that they could not see it becoming useful, it was also coded here, since usefulness was obviously a concern to the interviewee. Whether the information they mentioned was factually correct was considered irrelevant.

Affective

Phrases coded under this node were rooted in emotion. Phrases coded under this node generally included comments about their past experiences with a type of scientific information, the delivery of that information and occasionally, the people presenting it. At times, the spoken words themselves did not reflect emotion, but the tone of voice or body language during the interview clearly did. Being present during each interview was therefore beneficial for the coding of the transcripts. The decisions to code phrases under this node are clearly subjective, and up to the interviewer/coder's best judgement. For example, there were instances where scientists became quite emotive about a certain piece of scientific information that was poorly presented, or came from poorly executed research. The words alone might appear to fit better within the cognitive node, however, the emotional tone justified their inclusion in this node as well.

Investment: time

Phrases coded under this node were about the amount of time necessary to uptake new information being a consideration. Most of the comments were about how being time poor conflicted with their desire to take up, maintain their exposure to, or actively seek out more scientific fisheries information that they were interested in.

Investment: money

Responses coded under this node were comments on the monetary expense of materials of interest limiting the interviewee's willingness to uptake a new piece of scientific information or improve their understanding of it.

4.4 Results and discussion

The results and discussion have been organised in sections that address the research questions, the implications of these findings for fisheries management, and directions for future research.

4.4.1 Evidence of informal learning

Fisheries managers, scientists, and commercial and recreational fishers all spoke freely about information that they had learned informally. Some of these quotes are presented in the following paragraphs. More evidence of informal learning in interviewees is included in Table 4.2. The quotes presented here represent examples of information that individual stakeholders had learned in work environments, from meetings with government employees/scientists, and from government publications intended for the public. Table 4.2 is not intended to be exhaustive, but serves as an example of the more typical responses among the stakeholder groups.

Many responses from managers indicated informal learning in the work environment. For example:

"I think the yellow zones in their current form are very hard to defend ... They're seen as recreational fishing areas, it's not their purpose… And there's no doubt, we've lived and learned that we could do a better job with zoning..." (**Manager 7**)

"I think the science behind the zoning is always going to be imperfect ... the biological perspective is relatively easy. The system may be complex, but it's fairly easy to draw lines on maps and have certain proportions of areas that are set aside for conservation, biodiversity conservation, it's more difficult to look at the collateral damage, if you will, by restricting access to certain zones... and what sort of compensation is going to be needed?" (**Scientist 5**)

These quotes indicate how these two individuals have learned retrospectively from previous experience regarding marine park planning. These stakeholders took up new information in a professional setting, engaged with it cognitively, and extended/changed their conceptualisation of a system. The finding that managers and scientists informally learn fisheries related information in a professional setting is in keeping with previous research. Multiple studies have detailed the complications and difficulties associated with managers and scientists informally learning multidisciplinary and multi-jurisdictional information in fisheries and marine park planning contexts (Clay and Goodwin, 1995; Endter-Wada et al., 1998; Jacobson and McDuff, 1998; Cvitanovic et al., 2014).

Table 4.2 Supplementary quotes suggesting the occurrence of informal learning.

Stakeholders	Quotes
Commercial fisher 1	*"Of course. Well they've done their science on what fish for instance, the coral trout, by the time it gets to a legal size, it's usually had a chance to breed, it's a female, while they're little. Like the barramundi, they're female when they're big, so they're the maximum size."*
Commercial fisher 4	*"If the TAC was reduced on the coral trout, and it was extended across all three sectors, you might be able to look at reducing the size limit of the minimum take of coral trout. But while there's no control over the recreational and charter and latent effort growth in those industries, I don't think you can remove any measure you've got at the minute to protect stocks. With mackerel, the size limit should probably be increased if anything."*
Recreational fisher 3	*"... Each breeds a different size and some fish breed more once they get over a certain size, like barra, the big females breed more, that's why the 120 maximum's on them, same as groupers and that sort of thing."*

The quotes regarding size limits from recreational and commercial fishers presented in Table 4.2 are examples of individuals engaging with information taken up from meetings with government employees and government publications. The rationale behind minimum and maximum size limits is published widely in articles and brochures aimed at sectors of the public. The information is also often the subject of fisheries reviews, and therefore stakeholder meetings/consultations. However, knowledge of this rationale is not required for fishers to abide by the law or perform their lifestyle activity. Therefore, a fisher's awareness of the rationale behind minimum and maximum size limits, and their effort to engage with the information and formulate an opinion, is very likely evidence of voluntary, informal learning [Table 4.2]. The willingness of fishers to voluntarily uptake, and engage with, scientific information relevant to their activities in informal environments (i.e. through informal learning) is also well documented in existing literature (Degnbol, 2005; Frank et al., 2009; Li et al., 2010).

4.4.2 Proportions of stakeholders whose informal learning was influenced by each controlling/constraining variable

Table 4.3 has been constructed to illustrate the proportions of comments from stakeholders that describe each variable as being potentially important to their informal learning. The stakeholders have been grouped according to their primary role in fisheries management. Though some stakeholder groups appear to be unrepresented in some variables, the 0% should not be interpreted as a strict absence of potential effect, owing to the small sample size.

Table 4.3 Number of individual stakeholders whose comments provide evidence for informal learning (the independent variable) and variables affecting informal learning. Comments providing evidence for two or more variables are counted as being evidence for each variable (e.g. comments providing evidence for the cognitive and affective dimensions are counted twice)

Variables	Stakeholder groups	Percentage of individuals
Informal learning	Managers (N=8)	100%
	Scientists (N=9)	100%
	Commercial fishers (N=5)	100%
	Recreational fishers (N=7)	100%
Cognitive	Managers (N=8)	100%
	Scientists (N=9)	100%
	Commercial fishers (N=5)	100%
	Recreational fishers (N=7)	85.7%
Conative	Managers (N=8)	87.5%
	Scientists (N=9)	77.8%
	Commercial fishers (N=5)	80%
	Recreational fishers (N=7)	100%
Affective	Managers (N=8)	100%
	Scientists (N=9)	100%
	Commercial fishers (N=5)	100%
	Recreational fishers (N=7)	100%
Investments of time	Managers (N=8)	37.5%
	Scientists (N=9)	44.4%

	Commercial fishers (N=5)	40%
	Recreational fishers (N=7)	28.6%
Investments of money	Managers (N=8)	12.5%
	Scientists (N=9)	0%
	Commercial fishers (N=5)	0%
	Recreational fishers (N=7)	14.3%

4.4.3 Identification of variables influencing informal learning

All of the variables shown in the literature to influence informal learning were present in the fisheries stakeholders interviewed. The evidence for each of the key variables is addressed in this section. Each section includes an interpretation of the evidence for each variable/constraint and a justification for its inclusion as evidence for that particular variable/constraint. For ease of reading, only the most representative quotes are presented in-text (i.e. those quotes that are most explicitly relevant to the variables in question), and additional quotes can be found in the tables towards the end of each section. These quotes were selected because they best illustrated the effects of each variable, and the relationships between them; they should not be considered exhaustive and are not intended as such.

Cognitive

The cognitive dimension describes how well (or not) the information aligns with individuals' existing knowledge, how easy they find the information to digest/engage with, and whether they can understand it well enough to see a potential use for it (Shrigley et al., 1988; Alsop, 1999). Therefore, any quotes from stakeholders that aligned with these characteristics were coded under the cognitive dimension.

The cognitive dimension was important for fisheries stakeholders from all groups [Tables 4.3, 4.4]. However, the cognitive context of individuals within and between stakeholder groups (i.e. managers, scientists, commercial and recreational fishers) differed in some instances.

Managers generally considered peer review and adherence to scientific rigour to be their cognitive standard:

"From a scientific perspective, peer-reviewed journals are definitely the most trustworthy… I place such an emphasis on peer review because it seems to be our culture – it's not an opinion of one person, it's been independently and confidentially reviewed to be of a certain quality that it can be published." (**Manager 1**)

The cognitive dimension drove scientists and scientifically trained managers to scrutinise new scientific information using scientific rigour. At times, an inappropriate presentation or interpretation of data, or scientific information outside of their own discipline elicited affective responses, suggesting that at least in some scientifically trained managers and scientists, the two dimensions are closely tied together:

"I have a major problem with fisheries genetics… and usually I'm suspicious of anything geneticists present. I feel like they don't explain the concepts properly. I usually don't trust what they present. Genetics works very well at identifying stock structures, but when they try to do other things I don't understand it... They talk about stock structure, and I can understand that, but when geneticists talk about anything else, I'm deeply suspicious." (**Scientist 3**)

This phenomenon might be part of the reason why the social sciences have historically met with resistance in management agencies where the majority of managers and scientists are trained in the natural sciences (Clay and Goodwin, 1995; Endter-Wada et al., 1998; Jacobson and McDuff, 1998; Ewel, 2001).

The cognitive dimension also came into play among commercial and recreational fishers. However, rather than cognitively engaging with the information using an abstract concept such as scientific rigour (as scientists and scientifically trained managers did), commercial and recreational fishers generally appraised the quality of information by comparing it with their own knowledge and experiences in the field:

"…if I'm not happy with what science is saying because it contradicts what I feel at [**a**] *grass roots level… I would make the effort to look or enquire if there was an alternative science to that argument, you know?"* (**Commercial fisher 2**)

"Mate, it just depends whether I've seen this article happening in real life. You know, I mean, if they turn around and say trout stocks are on the decline, and we can bag out every time we go, I'm going to think it's dubious to say the least... I would have to stack it up against [sic]... my personal experience, you know, at the time." (**Recreational fisher 4**)

This finding is in keeping with multiple studies that have found fishers have the tendency to contextualise new information with their existing local knowledge of a fishery (Degnbol, 2005; Gray and Jordan, 2010; Gray et al., 2012). A few fishers who had previous and existing experiences with fisheries science or relationships with scientists/managers did mention the value of peer review and scientific rigour when scrutinising scientific information [Table 4.4]. These fishers did not have any scientific training, so their application of scientific rigour suggests that good relationships between fishers and scientists/managers could affect the way fishers cognitively scrutinise/engage with new scientific information.

It is apparent that the cognitive dimension is both applicable and potentially important for informal learning in all fisheries stakeholders. This dimension has proven flexible enough to capture the different ways fisheries stakeholders are scrutinising scientific information by comparing it with their past experiences, existing perceptions of the system, and their senses of logic. Therefore, the cognitive dimension should be included in the conceptualisation of informal learning in fisheries stakeholders.

However, the flexibility of this dimension also creates difficulties. The results clearly show that fisheries stakeholders cognitively assess their information differently, varying from the adherence to scientific rigour, to whether the information matches with their real-world experience. There is therefore unlikely to be a single universal message that could appeal to the cognitive dimension in all fisheries stakeholders. Likewise, it is unlikely that a single communication strategy/model could be applied to stimulate the informal learning of a piece of scientific fisheries information in all fisheries stakeholders.

These findings agree with past studies suggesting the need for specificity and direct relevance to the audience when formulating communication strategies aimed at sectors of the public (both scientifically trained and otherwise) (Ham et al., 1993; Fensham and Harlen, 1999; Cvitanovic et al., 2014). To ensure the maximum uptake of scientific fisheries information in a specific group of fisheries stakeholders, it will be necessary to know how that specific group cognitively evaluates/engages with information.

Table 4.4 Supplementary quotes suggesting the presence of the cognitive dimension.

Stakeholders	Quotes
Manager 2	*"The peer-reviewed system's got the lot. I think it's fraught with bloody issues, but unfortunately, there's nothing better, and I can't tell you anything that's better…"*
Manager 4	*"… one of the things that's most important for me … is to maintain a very close personal and professional relationship with a lot of the* [**scientists**] *themselves… it allows me to discuss certain issues with the scientists, their perspectives, and being able to sort of bash ideas around, and I think that's actually a critical part of being an effective resource manager."*
Scientist 4	*"… they clearly had no background understanding of the fishery, of the shortcomings of the data that they were using… and the way they were presenting it was "Oh, my God..." … I don't really think you can draw those conclusions based on that dodgy set of data…"*
Recreational fisher 1	*"Peer-reviewed, academic journals. I think they're subject to greater scrutiny… they tend to be based on more reliable data.... they're peer-reviewed, and also, because I think they are written with an expectation of challenge in mind. They're not written to persuade, they're written from a position of factual basis."*
Recreational fisher 5	*"I like to actually find out how the sampling or how the information has been acquired. Quite often … they'll be making an assumption based on a ten thousand dollar research. One weekend out at the reef, they spend their ten grand and they survey two reefs, and they take the information and extrapolate it out to cover the whole Northern region or whatever."*
Recreational fisher 7	*"…the pure science that comes out of independently funded organisations whether they be university, AIMS, so forth, GBRMPA which aren't driven by commercial considerations, I think are the most trustworthy."*

Conative

The conative dimension describes how regularly useful the information appears to an individual (Shrigley et al., 1988; Alsop, 1999). The more relevant the information is to an individual's daily activities, the more likely the information will be to appear regularly useful, and the more likely that individual will be to uptake the new information (Shrigley et al., 1988; Alsop, 1999; Fensham and Harlen, 1999).

The conative dimension was important to all the stakeholders interviewed [Tables 4.3, 4.5]. However, how the conative dimension was expressed differed between the stakeholder groups. Fishers were comparing the scientific information or what the information had to offer, to their own extensive experiences in the field and drawing relevance between the information and their own activities.

Commercial fishers tended to rely on the conative dimension quite heavily when assessing new pieces of information. Many stated that the new information needed to be immediately relevant to their activities and their businesses if it was to be considered interesting and worthy of pursuing:

"The research, whatever persuasion it is, is only as useful to fishermen as we can actually apply it and get real traction … There has to be a relevance, definitely, but then we have to use that relevance, learning, whatever you want to call it to actually improve what's happening today." (**Commercial fisher 3**)

Recreational fishers placed great importance on the conative dimension to the extent where they often sought information they felt might be useful to their activities:

"Yeah, there's a few bits of information [**referring to barotrauma papers**] *like that sort of thing, but I don't do much of that style of fishing anyway…"* (**Recreational fisher 2**)

This finding is in keeping with previous research, which found most fishers would be interested in scientific information that would make their fishing better, or more environmentally friendly (Li et al., 2010).

The conative dimension was also important to managers and scientists. Many managers and scientists primarily sought and took up scientific information with a direct relevance to their occupations and roles at the time:

"Professionally, my interest in this largely is professional and its relation to management decisions and government arrangements in fisheries, as a recreational fisherman…" (**Manager 3**)

However, some managers and scientists also expressed an interest in information that was not necessarily directly related to their present occupation or role:

"I mean I have been trained in looking at squids, so I have a hobby interest in squid fisheries and in trying to look at the potential to develop a squid fishery in Queensland, so I keep my eye on the literature in the squid arena in terms of tropical squid fisheries, and tropical squid biology and ecology. So I maintain interest in that as well too." (**Scientist 5**)

Much like the cognitive dimension, the conative dimension appears to apply to the full range of fisheries stakeholders, while being discrete enough to be useful as a variable for modelling informal learning in the future. However, these results suggest that fisheries stakeholders find information useful for different reasons, and this needs to be considered in communication efforts aimed at specific stakeholder groups. It is unlikely that the conative dimensions of all fisheries stakeholders could be appealed to with one message, or a specific piece of scientific information. This finding is in agreement with existing literature, which suggests the way people evaluate a piece of scientific information, and their decision of whether to uptake it is highly contextual and case-by-case in nature (Wynne, 1993). Therefore, while improving the perceived regular usefulness of new information might be beneficial for targeting certain stakeholder groups (e.g. commercial and recreational fishers), it is important to understand and identify what that entails for the target audience. It is of crucial importance to understand how, or even whether it is possible to make a piece of scientific information appear regularly useful to the target stakeholder group or sector(s) within any one stakeholder group.

Table 4.5 Supplementary quotes suggesting the presence of the conative dimension.

Stakeholders	Quotes
Manager 4	*"Personally, I'm actually interested in a pretty broad range of fisheries science ... I'm certainly interested in the information that's most relevant to the GBRMP, and also in the species that I target as a recreational fisher, or that I'm in the charter to manage as part of my job here at the GBRMPA. I'm also really interested in fisheries science more generally, so I have an interest in international fisheries science, international fisheries legislation and international fisheries management."*
Manager 8	*"My capacity as* [**recreational**] *fishing manager, I don't find fish stock issues particularly useful to what I'm dealing with. My job as* [**recreational**] *fishing manager is more about a people based, or an*

	expectation based management, so this is information that is useful to me, but certainly not critical…"
Scientist 4	*"I've certainly come across the social type fisheries sciences before. I haven't been able to pay as much attention as I would like to do, more of an interest rather than a necessity."*
Scientist 7	*"I feel a bit mean saying that I don't use the natural sciences actually ... I think it does make me a better social scientist, because I think social* **[sciences]** *are limited in understanding … the way people are going to be impacted by change is through changes that occur in the natural system … I really think that understanding the link, what's the relationship between people and fisheries resource, natural resource, is quite important to being a good social scientist. We can't just look at the society aspect by itself in isolation. We need to understand the context…"*
Commercial fisher 4	*"But what's it gonna teach me about fishin'? I mean, in all honesty, what's it gonna tell me if I'm a new participant in the game, or even if I'm in the game, I'm not gonna learn anything from that. I might find a few little things interesting and a few little things I could say "I told you so" too, but I don't know what it's gonna teach me."*
Recreational fisher 4	*"To be quite honest, you know, where they're catching the fish is not exactly relevant to me … I mean, I can certainly see the validity in having information like that available, but for me … I don't think I could use something like that in everyday use, no."*
Recreational fisher 5	*"If I wasn't a fisherman I probably wouldn't be interested in this kind of information."*

Affective

The affective dimension describes any emotional attachments, associations or feelings related to the piece of information being delivered (Shrigley et al., 1988; Alsop, 1999). The affective dimension is less discrete, and harder to measure than the other variables presented thus far. Emotion is difficult to measure is nuanced, and exists along a continuum, and existing tools used to describe emotions associated with speech are often problematic (Cowie and Cornelius, 2003). Therefore, in this study, no effort is made to distinguish between or describe exact emotions, and the results and interpretations presented below merely point out that emotion had an influence on stakeholders' informal learning of scientific information. Changes in body language and tone of voice during the interviews were interpreted as being suggestive of emotional affect, even though the words themselves did not necessarily convey that affect [Table 4.6]. Owing to the difficulty of detection, it is likely that the affective dimension is under-represented in the results despite clearly having an influence on informal learning, and possibly playing a part in stakeholders' initial judgements of an information source/presenter. In some cases, results also suggest that the affective dimension appears to co-occur with one or more other variables [Table 4.6].

Many scientifically trained managers had strong emotional reactions when they felt scientific rigour was not adequately adhered to, or when bad science was published:

"I'm sure you saw Channel nine's attempt at the marine parks debate on 60 minutes. That was some of the worst journalism I'd ever seen. It was value laden, lop-sided ... negligent of fact, and just using discredited data, continually discredited data, continues to be popping up. It's well known in some of the literature that some of the data is inaccurate, incorrect..." (**Scientist 1**)

"To tell you the truth, I get a bit depressed when reading these papers, because I question the motivation and the objectivity of the way some of these things are written, I really do..." (**Manager 2**)

The results here, suggest that the cognitive and affective dimensions can be quite tightly linked in managers and scientists. The linkage between the cognitive and affective dimensions in managers and scientists might partially explain the resistance that disciplines such as ecology and the social sciences faced upon their introduction to fisheries managements [Table 4.6] (Clay and Goodwin, 1995; Endter-Wada et al., 1998; Ewel, 2001). The social sciences in particular, have historically met with resistance upon their introduction to fisheries management because they were deemed less rigorous by existing managers and scientists who were trained in the natural sciences (Clay and Goodwin, 1995; Endter-Wada et al., 1998; Ewel, 2001).

Among commercial fishers, the affective dimension seemed to come into play when assessing a new source of information, or individual. However, the affective dimension also appeared to be associated with investments of time, and therefore money:

"We haven't got the time, and we haven't got the ability to just stop running our businesses to go and have input into projects that are funded for the people doing it" (**Commercial fisher 4**)

The linkage of the cognitive and affective dimensions in commercial fishers is not well represented in the findings of this study (i.e. No quotes from commercial fishers could be easily and explicitly attributed to linkages between these dimensions to the exclusion of others). However, cognitive dissonance (i.e. the incompatibility of the new information with fishers' existing knowledge) between scientific information and commercial fishers' conceptions of a system has been the cause of significant management conflicts in the past (Steele et al., 1992; Degnbol, 2005). Therefore, the lack of evidence for connections between the cognitive and affective dimensions in commercial fishers should certainly not be considered evidence of the absence of the aforementioned linkages, but rather, reflective of the small sample size.

Table 4.6 Supplementary quotes suggesting the presence of the affective dimension.

Stakeholders	Quotes
Scientist 3	*"I have, but I don't like it. I just think it's a waste. I don't like FRDC and FRDC seems to be funding a lot of stuff that isn't really scientific. So I think it's a waste. I don't like economists anyway. I have a special objection to funding economics."*
Commercial fisher 4	*"I think for me, what I take notice in fisheries science is the person that's given the presentation, and if I feel a sense of "I trust 'em", and there's a human likeability to that person, I think you tend to listen more, you tend to trust more. And you also tend to want to give more information to that person."*

The relationships between the affective dimension and other variables will require further study to clarify. However, the tight linkages between this dimension and others discussed in this study clearly indicate that the affective dimension should be included in conceptualisations of informal learning in fisheries stakeholders. The nature of the affective dimension's influence and potential relationships with other variables have proven harder to detect and define than those of other variables identified in this study. Therefore, any modelling technique used to model informal learning in fisheries stakeholders will likely require the capacity to convey multi-directional interactions between variables of varying intensity and nature (i.e. positive/negative).

4.4.4 Identification of constraints to informal learning

This study identified two variables that appeared to be acting as constraints on fisheries stakeholders' informal learning, and their willingness to learn informally. The two variables, investments in money and investments in time, have been suggested to constrain informal learning among conservation managers/planners, and environmental behaviour in members of the public (Tanner, 1999; Sutton and Tobin, 2011; Cvitanovic et al., 2014). The findings of this study indicate that the effects of investment in money and time are also relevant to fisheries stakeholders, and these two variables have the capacity to constrain/limit stakeholders' abilities/willingness to informally learn scientific information that they would otherwise find interesting. As with the previous sections, only the most representative quotes are presented in-text, and additional quotes can be found in the tables towards the end of each section.

Investment: money

Monetary investment was identified as a constraint by fisheries managers and recreational fishers in this study. However, the small scale of this study means that an absence of evidence for its effect upon other fisheries stakeholders (i.e. scientists and commercial fishers) should not be interpreted as evidence of absence. Monetary investment has been identified as being a constraint on environmental activities in the past (Tanner, 1999; Sutton and Tobin, 2011). Table 4.8 also presents evidence of an instance where a commercial fisher associates investments of time with investments of money. While it might be assumed that commercial and recreational fishers are more likely to be faced with having to invest money to access scientific information, it would appear that managers, too, can be faced with needing to pay for their information:

"I suppose like I said, I don't necessarily use some of the journal searches as my first port of call. Here you have to be a member, paid up member, or access through a university, so that's probably why I use google more often than anything else." (**Manager 5**)

Many of the fisheries managers and scientists interviewed in this study belonged to government agencies subscribed to multiple scientific journals and with substantial libraries. However, the results of this study suggest that this fact does not necessarily mean that these stakeholders have free access to all of the information they might find interesting or relevant. The sheer number of existing journals and publishers makes subscription to every journal/publisher prohibitive. Therefore, even those stakeholders working in large academic institutions or government agencies cannot be considered immune to the effects of monetary investment.

Table 4.7 Supplementary quote suggesting the constraining effect of investments of money.

Stakeholders	Quotes
Recreational fisher 6	*"…a lot of those other resources are available to the public on a paying basis. That sort of stands up as a little bit of a barrier to Joe Public, Joe Public says "Oh, it's a scientific paper, I may or may not understand, you know, I'm not going to pay $5, $6 to get a PDF, there's more stuff to do on the computer, I'll just check my email or something or read about it for free"."*

Investment: time

As the literature suggests, investments of time were considered a constraint for fisheries stakeholders (Tanner, 1999; Sutton and Tobin, 2011; Cvitanovic et al., 2014). Among all the stakeholders (i.e. managers, scientists and commercial and recreational fishers, the investments of time necessary to access and consume new scientific information proved to be a limiting factor [Table 4.8]. Investments of time were found to constrain stakeholders' abilities and willingness to access and consume scientific information.

Many of the managers spoke of needing to change the way they access scientific information, relying less upon primary literature (which many deemed to represent the highest standard for scientific information) due to time pressures [Tables 4.4, 4.8]. For example:

"And the main reason for that for me is probably just a lack of time to be able to become intimately familiar with how to drive those systems and interrogate them, but I know people who know how to use it, so if I have a specific question, I quite often just go and ask them and they go and generate the information for me… Time's the major constraint there." (**Manager 4**)

While the results indicate that investments in time appear to constrain fisheries stakeholders' informal learning, this survey design did not offer enough resolution to identify which kind of constraint it might be (i.e. objective or subjective). An objective constraint that comes into play after an individual has decided they wish to learn the new information, or a subjective constraint where an individual loses interest in learning the new information because they feel it would require an investment in time (Tanner, 1999; Sutton and Tobin, 2011). Moreover, it is unclear from the results how the constraint of investment in time might be mitigated, although it is clear from these results that different stakeholder groups will have different coping mechanisms. Managers and scientists have well established professional networks they can use to correspond with investigating scientists, reducing the amount of time expended on gaining new information, and often rely upon these when time constraints make reviewing the primary literature prohibitive (Cvitanovic et al., 2014). Most commercial and recreational fishers, however, do not have such resources at their disposal, and since most agencies are more interested in improving the communication of scientific information to fishers (as opposed to their managers and scientists), this situation is problematic.

Table 4.8 Supplementary quotes suggesting the constraining effect of investments of time.

Stakeholders	Quotes
Manager 2	*"… trying to keep across it* [**new literature**] *in a satisfactory way is pretty hard. For us to do it properly, you probably need to set aside you know, 4 or 5 hours a week to do it right, and I'll tell you, nothing like that happens."*
Manager 5	*"I mean I've definitely gone to talk to the experts rather than start from scratch myself, so just gives you a bit of a head start in terms of finding the relevant information that you need."*
Scientist 4	*"I do leave some of the more scientific stones unturned … Just because I don't have enough time in the day."*
Scientist 5	*"Part of the challenge of course, is the usual thing of mailbox being overloaded on a daily basis and the challenge of being able to get back to pick up on all those different pieces of information that are coming through."*
Commercial fisher 2	*"You see, most of these guys are so consumed into just being able to fish, keep their boats working and keep some sort of normality within their social life with their families, that most of them, anything outside of that, is a big effort."*
Commercial fisher 4	*"We haven't got the time, and we haven't got the ability to just stop running our businesses to go and have input into projects that are funded for the people doing it."*

Recreational fisher 1	*"I accept that there's a good deal of data available to me that I haven't bothered to track down, just because it's too much effort involved in getting it. For example, I'm not prepared to go out to the university and spend days trawling through papers, looking for things."*
Recreational fisher 6	*"Things that you read about or hear about that you haven't really had too much time to look into. Stuff like sea surface temperatures, most of that data, like accurate, very up-to-date data is available on a paid basis."*

4.5 Summary and conclusions

As discussed in the sections above, the variables identified in this study (i.e. the cognitive, conative and affective dimensions, and investments of money and time) are in agreement with much of the existing literature (Shrigley et al., 1988; Lieberman, 1990; Ham et al., 1993; Weeks and Packard, 1997; Alsop, 1999; Ross et al., 2003; Degnbol, 2005; Ward and Wilkinson, 2006; Sutton and Tobin, 2011; Ham, 2013). Alsop's Informal Conceptual Change Model and its components have proven a suitable foundation for a new model illustrating informal learning in fisheries stakeholders (Alsop, 1999). The findings that individuals' existing knowledge and interests are important when they contextualise and relate to new, scientific information is also well supported in the literature (Shrigley et al., 1988; Alsop, 1999; Fensham and Harlen, 1999). Moreover, many existing mass communication frameworks also consider the relevance of a message to the target audience's values, motives or activities to be a major determining factor for the successful uptake of that message (Ham et al., 1993; Ross et al., 2003; Ward and Wilkinson, 2006; Ham, 2013). Therefore, it would appear that even with a relatively limited sample size, this case study uncovered variables influencing informal learning in fisheries stakeholders that are confirmed and supported by existing literature.

The complex and nuanced relationships between the variables identified in this study are difficult to convey in an illustrated model. This is possibly why past models, such as Alsop's ICCM, have simply indicated that the dimensions/variables are related to one another, but have not portrayed those relationships at any greater resolution. Figure 4.2 is an attempt at a new conceptualisation of the variables influencing the informal learning of scientific information among fisheries stakeholders that attempts to convey the nuance and complexity of the relationships between the component variables. Overlapping circles are used in this model to convey the fact that the variables do not necessarily exist as discrete entities, and that they can also operate in tandem. The relationships between these variables are also not necessarily linear.

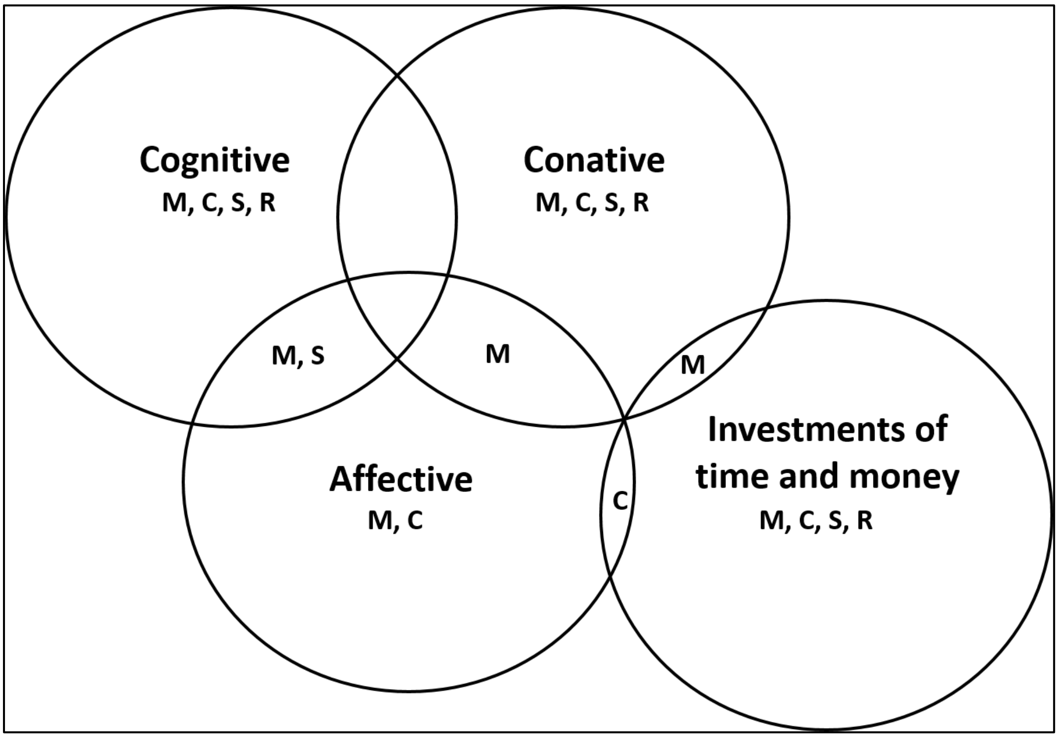

Figure 4.2 Conceptualisation of the variables controlling informal learning in fisheries stakeholders (i.e. fisheries managers, scientists, and commercial and recreational fishers) and the relationships between those variables based on the results presented in Tables 4.4 - 4.8, and discussed in this chapter. C = commercial fisher, M = manager, R = recreational fisher, S = scientist. The letters in each segment represent instances where one or more interviewees from each stakeholder group made comments relevant to each variable, or where the variables intersect.

The findings of this study suggest that any single model of or approach to informal learning is unlikely to be applicable across all the stakeholder groups (i.e. managers, scientists, and commercial and recreational fishers). The nature (i.e. positive or negative effect) and intensity of the relationships between the variables influencing informal learning are likely to vary between stakeholders with different interests and relationships to the information being presented. For example, the informal learning models of fisheries scientists seeking information in a professional context are likely to differ somewhat from those of recreational fishers seeking information that might improve their fishing. It is highly unlikely that a generic model of informal learning of scientific information among fisheries stakeholders could be constructed with any confidence. Ideally, different models should be constructed for different stakeholders based on their different relationships to the fishery, the information topic and, potentially, the behaviour associated with that information (i.e. change in fisheries regulations, community monitoring etc.). However, there is the risk that the target audiences' perceptions of a piece of scientific information and its implications might change during the time it takes to develop a specific model. This demand on timeliness, and the aforementioned unlikely success of a generic model, means that researchers and outreach professionals need a method for the rapid elicitation of high resolution, informative mental models regarding stakeholders' informal learning.

5. Mapping recreational fishers' informal learning of scientific information using a fuzzy cognitive mapping (FCM) approach to mental models

This chapter builds upon Chapters Three and Four, which identified several important drivers and constraints affecting informal learning in the literature, and validated their importance for fisheries stakeholders. The chapter validates the importance of the drivers and constraints identified in the earlier chapters to fisheries stakeholders by piloting the Fuzzy Cognitive Mapping (FCM) approach on recreational fishers to model the thought processes contributing to their informal learning. Recreational fishers were selected as the pilot group for this study because less is known about their communication needs despite the fact that they have historically been well researched as a stakeholder group. Recreational fishers were also easier to sample in a large enough number to meaningfully test the applicability of the FCM approach in a limited amount of time.

This chapter demonstrates that it is possible to generate meaningful, informative models detailing the variables influencing recreational fishers' informal learning and the relationships between these variables. This chapter also applies novel data analysis techniques to the resultant FCM representations of mental models to gain further insight into how the communication of science to recreational fishers can be strategically improved.

Note: The bulk of this chapter (i.e., everything except the application of network analysis techniques to FCM representations of mental models) has been accepted for publication in *Fisheries Management and Ecology*. The network analysis is included here to lend additional rigour to the interpretations of the data submitted for publication, but was not included in the publication due to space limitations imposed by the journal. Because this chapter was written as a stand alone paper, there is some repetition of the literature review and introductory materials. Also, in this chapter, the term 'fishers' refers only to recreational fishers.

5.1 Introduction

There is a growing need to better understand how to communicate scientific information to fisheries stakeholders, including recreational fishers. The modern active-adaptive approach to fisheries -- which requires that management actively adapts to changes in actual or perceived risks to the fishery, the ecosystem, or the fishers (Gray and Jordan, 2010) -- relies on effective communication of scientific information between a growing range of stakeholders during all stages of the management process (Endter-Wada et al., 1998). Management can only adapt to actual or perceived risks if the nature and presence of these risks is communicated quickly and effectively between a range of stakeholders including resource users, researchers, and managers (Granek et al., 2008; Gray and Jordan, 2010; Gray et al., 2012). Likewise, management changes responding to risks are less likely to translate into behavioural change in stakeholders, such as compliance with management measures, without high levels of communication, understanding and engagement of stakeholders in the decision making process (Weeks and Packard, 1997; Schusler et al., 2003; Kaplan and McCay, 2004). The effectiveness of modern fisheries management therefore depends on how effectively information is communicated from a range of scientific disciplines (social, economic, and ecological) to a diverse range of fisheries stakeholders. Despite the need for a better understanding of issues surrounding the communication and uptake of scientific information in fisheries management, this is an area that has received little formal attention from a research perspective. As fisheries management becomes increasingly more adaptive, inclusive and multidisciplinary, there comes an increasing need to understand the manner in which scientific information is communicated within and between increasingly diverse stakeholder groups, and the factors that influence stakeholders' understanding and uptake of scientific fisheries information.

To communicate effectively with fisheries stakeholders, it is imperative to understand how different stakeholders relate to a resource and its management given the varying ways that these groups conceptualise fishery resource systems, their role within these systems and what they ultimately receive from fishing activities (Gray et al., 2012; Gray et al., 2015). As a stakeholder group, recreational fishers have been well researched, and the ways they interact with and conceptualise fisheries, and their expectations are well understood (Bryan, 1977; Ditton and Fedler, 1984; Matlock et al., 1988; Fedler and Ditton, 1994; Hunt and Ditton, 1996; Graefe and Ditton, 1997; Sutton and Ditton, 2001; Ditton and Stoll, 2003; Henry and Lyle, 2003; Ditton and Sutton, 2004; Sutton, 2005; Sutton and Ditton, 2005; Sutton, 2006; Granek et al., 2008; Lloret et al., 2008; Gray and Jordan, 2010; Li et al., 2010).

Recreational fishers are unique among fisheries stakeholders for several reasons. There is a heterogeneity in their values and behaviours (e.g. their consumptive and non-consumptive use of resources) (Matlock et al., 1988; Ditton and Fedler, 1989; Sutton and Ditton, 2001; Ditton, 2002; Sutton, 2003; Arlinghaus, 2007; Arlinghaus et al., 2007). Recreational fishers also interact as a community despite being widely distributed, relying heavily on informal and remote means of communication (Ditton et al., 1992). Despite this, recreational fishers' communication needs and relationships with scientific fisheries information are the least well understood of any group engaged in fisheries management (Clay and Goodwin, 1995). Indeed, it is recognised that more effort needs to be made to actively engage recreational fishers in fisheries science and management on a global scale (Gray and Jordan, 2010; Frank et al., 2009; Granek et al., 2008; Burger et al., 2001; Clay and Goodwin, 1995; Jentoft, 1989). Consequently, there is a need for a theoretical understanding of how recreational fishers perceive, uptake, and use (or not) scientific information and how the communication of scientific information to this diverse but important stakeholder group can be improved.

There is a need to better understand recreational fishers' communication needs despite this group being otherwise well researched. Additionally, recreational fishers outnumber all other fisheries stakeholders discussed in this thesis (i.e. managers, scientists and commercial fishers), and they can be efficiently sampled at fishing tackle retail outlets, which they frequent. These combined reasons make recreational fishers excellent candidates for piloting this study.

The aim of this chapter is to improve the understanding of recreational fishers' communication needs by using a sample of recreational fishers from Queensland, Australia to investigate the following questions:

1. What are the most relevant factors that influence recreational fishers' uptake of fisheries science?
2. What are the most significant factors that limit recreational fishers' uptake of fisheries science-related information?

The goal is to provide empirical support for the adoption of new strategies that facilitate the effective communication of scientific information to recreational fishers. The study builds upon previous research focused on understanding factors that influence the uptake of scientific information among lay-people, but applies the relevant concepts in the novel and understudied context of recreational fishing.

5.2 Conceptualising and operationalising informal learning

Early efforts to communicate scientific information to fisheries stakeholders assumed that stakeholders would passively take up and use the information provided to them (Weeks and Packard, 1997; Miller, 2001; Sturgis and Allum, 2004; Sanderson et al., 2005). However, attempts to communicate to fisheries stakeholders in that way have led to conflict and other undesirable outcomes, suggesting that the assumption that stakeholders will passively absorb scientific information in a predictable and positive way is faulty (Clay and Goodwin, 1995; Fitzpatrick et al., 2011). The results of these earlier efforts suggest that a better model is necessary to understand how fisheries stakeholders perceive, process and take up (or not) scientific information.

One concept that can guide explorations into how to improve the way scientific information can be communicated to fisheries stakeholders is informal learning. Informal learning occurs with no formal educators, outside of a formal educational environment, and with no formal assessments or consequences for not taking up the material (Alsop, 1999). Informal learning is how most adults take up information in their everyday lives. Recent research into science communication and the informal learning of scientific information has identified several factors that might influence stakeholders' uptake of scientific fisheries information in a recreational fishing setting. As described in Chapters Three and Four, Alsop's (1999) Informal Conceptual Change Model (ICCM) captures and encompasses many of the variables used in the literature to conceptualise informal learning. This model identifies three dimensions adapted from attitude research to describe the public's uptake of scientific information (Shrigley et al., 1988; Alsop, 1999). These are: cognitive, conative and affective dimensions (Alsop, 1999). The cognitive dimension describes how closely the new information aligns with individuals' existing knowledge, their sense of logic, how clear the message is, and whether they can perceive a use for the information (Shrigley et al., 1988; Alsop, 1999). The conative dimension describes how regularly useful the individual finds the information i.e. how relevant the information is to his/her chosen activities (Shrigley et al., 1988; Alsop, 1999). The affective dimension consists of any emotions the individual associates with the new information (Shrigley et al., 1988; Alsop, 1999).

When applied specifically in a recreational fishing setting, more recent research has investigated the utility of some of these general and theoretical concepts of informal learning to fisheries, operationalising Alsop's ICCM to investigate the communication of scientific information to fisheries stakeholders (including recreational fishers) (Chapters 3 & 4). This research found that both informal learning and ICCM were useful and relevant, but also that additional variables such as investments of money and time influenced informal learning in fisheries stakeholders (Chapter 4). That research recommended that the relationships between the variables constraining and driving fisheries stakeholders' informal learning need to be investigated before a useful, informative model can be constructed. In addition, as novel variables were discovered in even a relatively small sample size, it was recommended that any research seeking to model informal learning in fisheries stakeholders should employ a methodology flexible enough to capture any unknown variables. In the present study, the findings of that research are extended by mapping out recreational fishers' thought processes via graphic networked representations of recreational fishers' internal mental models through a cognitive mapping approach to provide insight into structural relationships that influence informal learning.

One of the major factors limiting the understanding of recreational fishers' informal learning is the lack of precedent. While the literature identifies variables considered to be significant in influencing the uptake of information generally, it is quite likely that the connections between these variables are context and learner specific (Weeks and Packard, 1997; Alsop, 1999; Sturgis and Allum, 2004; Gray and Jordan, 2010). It is also possible that there are novel variables controlling recreational fishers' informal learning that are yet to be identified owing to the limited sample size in previous studies (Chapter 4). In this chapter, to better understand these issues, a fuzzy cognitive mapping (FCM) approach to mental modelling is used. FCM is a highly parameterised and weighted version of concept mapping that allows individuals and researchers to create a network representation of the relationships between variables within a knowledge domain (Kosko, 1986). This approach has been adopted to better understand the connected nature of the factors that limit or facilitate the uptake of scientific information in recreational fishers using the general components/concepts previously identified that constrain and influence the uptake of information but arranged by individual fishers (Alsop, 1999).

Aim: Given the lack of an integrated model of the factors that influence the uptake of scientific information, especially in the context of recreational fishers, the aim of this chapter is to model recreational fishers' thought processes associated with the informal learning of scientific fisheries information. This aim is achieved through the answering of the following research questions.

Research Questions:

1. What are the factors that most significantly facilitate or limit the uptake of scientific information in recreational fishers?

2. Are recreational fishers' informal learning models consistent, independent of their levels of interest in the scientific subject matter being presented to them?

3. Are the factors and relationships that facilitate or limit informal learning similar between recreational fishers?

4. How can answers to these questions help improve the communication of scientific information to recreational fishers?

5.3 Methodology

5.3.1 Identifying the relationships between factors that influence information uptake using a Fuzzy Cognitive Modelling approach

FCM generates a semi-quantitative, formatted and therefore directly comparable concept map that provides understanding of how individuals perceive and understand a system internally. Although there are a range of 'mental model' elicitation techniques (see Jones et al., 2011 for a review), FCM allows the knowledge of individuals to be compared across groups quantitatively to determine the different weights that people place on relationships and concepts in a cognitive map (Ozesmi and Ozesmi 2004; Jones et al., 2011). The premise of FCM is that participants are asked to assign relationships to either the freely associated or standardised list of components relative to a particular system. The assignment of weights and relationships is based on a participant's perceptions, thought to be similar to the way in which individuals have constructed internal versions of external reality in their minds (Gray et al., 2014). In this chapter, the FCM approach has been adopted to better understand the different factors that influence the uptake of information by recreational fishers, by allowing graphical representations to be developed that identify the important factors that influence the uptake of scientific information, the relationship between factors and the relative influence that one factor has on another. The FCM approach has been used in a variety of disciplines to model systems, including the physiology of appetite, political developments, electrical circuits, interactions between marine animals and the ecology of local fisheries (Gray et al., 2012).

5.3.2 Study site and sample size

The study sites were Gladstone and Townsville in the Great Barrier Reef Marine Park region in Queensland, Australia. Gladstone is located towards the southern-most boundaries of the Great Barrier Reef, whereas Townsville is the largest town towards the northern-most reaches of the Great Barrier Reef Marine Park.

Twenty-one recreational fishers from the Townsville area and nine from the Gladstone area were interviewed for this study. No sampling frame of recreational fishers in Queensland exists (i.e. there is no recreational fishing licence or record of who participates in recreational fishing), therefore fishers were sampled at local fishing tackle stores in Gladstone and Townsville. Over a period of four weeks, customers entering each fishing tackle store during opening hours (typically 9am to 5pm) were asked if they fished recreationally. Those who were fishers were then asked if they would like to participate in the study. Those who agreed (85%) were interviewed either on-site or at their convenience in a place of their choosing.

Two mental models, collected and represented through an FCM technique, were produced from interviews with each fisher, one representing their thought processes regarding the topic they initially found most interesting, and the other representing their thought processes regarding the topic they initially found least interesting.

Approval for this research was granted by the James Cook University Human Research Ethics Committee (Ethics application number: H4079), and all interviewees were asked to sign an informed consent form before the commencement of the research activity.

5.3.3 Interview design

The system fishers were asked to model included highly abstract variables they were unlikely to have an existing mental model for. Therefore, a different technique than usual was employed for this study. Cognitive maps are often obtained using four main methods: (1) through direct elicitation where interviewees are asked to arrange provided concepts/variables in an appropriate representation of their perceptions, (2) participatory modelling where individuals/groups are systematically asked who the major actors are, what the resources are, and the relationships between these actors and resources, (3) indirect elicitation where models are extrapolated from written texts, which can be elicited through interviews, and (4) through consensus analysis, which identifies shared concepts identified through open-ended interviews with participants, but does not focus on causal relationships between the major actors/variables (Jones et al., 2011). The approach adopted in this chapter combined aspects of all four common methods. As the respondents were unfamiliar with the system at hand, and the variables were also physically intangible, it was hypothesised that recreational fishers would likely find conceptualising the variables and then drawing mental models mentally exhausting, thus making the resultant mental models inconsistent and not truly reflective of their opinions. For the same reasons, it was deemed that asking recreational fishers to fill out a questionnaire about these variables in isolation might not truly capture their opinions and thought processes. Additionally, creating FCM representations of fishers' mental models was likely to be complicated by relying upon text elicited from open-ended questionnaires. Consensus analysis was also deemed inappropriate in this chapter because causal relationships are typically not captured using this technique (Johnson-Laird, 2001; Kolkman et al., 2005; Lindern, 2010; Jones et al., 2011; Gray et al., 2012; Gray et al., 2013a; Gray et al., 2014). Therefore, a combination of the questionnaire and interviewing approach was used. A semi-structured questionnaire was designed to cross-reference the variables of interest through questioning (i.e. fishers were led through the matrix). The intention was that any relationships between variables would be captured through thorough questioning about how each individual variable related to every other variable, and in both directions.

Offering standardised concepts to be used on the cognitive map can result in models that may not reflect the full range of system components perceived by individuals (Gray et al., 2014). To counter this, interviewees were asked whether there were any variables that they felt were important but not included in the list provided. The prescribed variables were based on the variables elicited from multiple fisheries stakeholders in Chapter Four, ensuring their applicability to a wide range of people and minimising the potential for multi-person bias.

Prior to their interviews where concept maps were developed, fishers were given three examples of scientific fisheries information [Appendix C]. The examples of scientific information were designed to appeal to the three major factors considered most likely to influence informal learning in fishers: the cognitive (e.g. the clarity of the information, and its adherence to an individual's sense of logic), conative (e.g. the perceived regular usefulness of the information) and affective (e.g. emotions attached to the information, its source, or its implications) dimensions from Alsop's Informal Conceptual Change Model. These variables were selected since they were expected to be important for fishers' informal learning based on the aforementioned previous work, and examples of scientific fisheries information appealing to these variables were easily found and translated into more colloquial terminology relevant to fishers (Chapters 3 & 4). Care was taken to ensure that each example of scientific information appealed to their relative variables as discretely as possible to minimise any confounding effects.

Example 1 (Cognitive): A tracking study about pigeye sharks in Queensland. This is a common and local species that inhabits inshore areas, but is not well known, nor presumed of particular interest to most fishers in the area. The novel example detailed the movement patterns of juveniles of this shark species. This example was included because it was assumed to contain no obviously useful information for fishers, nor anything that would necessarily stimulate emotion but was easy for fishers to interpret and digest. Therefore, this example targeted the cognitive dimension of Alsop's model alone since it was hypothesised to provide novel information unlikely to be directly relatable to participants' personal fishing behaviours.

Example 2 (Conative): A study of the feeding patterns of Queensland school and spotted mackerels. Both of these mackerel species are very popular and accessible species in the GBR region, particularly during the months these interviews were conducted in (July-August). This example detailed the seasonal diet of both species, and was intended to appeal to fishers' sense of usefulness, targeting the conative dimension in Alsop's model.

Example 3 (Affective): A study about the spread of anti-angling philosophy through Europe and North America, with no direct references to Australia. This example cited the increasing support for the animal rights movement that catch and release recreational fishing, a very common practice in the GBR region, constituted animal cruelty. This example was selected since it was hypothesised to have no immediately useful information to fishers, but was included as an emotional trigger, targeting the affective dimension.

Fishers were given these examples of scientific fisheries information for two reasons. The first was to give fishers examples of scientific information that appealed to each of the three dimensions in Alsop's ICCM (i.e. the cognitive, conative and affective dimensions) in isolation to the others. The second reason why fishers were given novel examples of scientific information in angling shops was to stimulate informal learning. Prior research into mental models has identified benefits of eliciting mental models in an *in situ* environment as opposed to an abstract one (Jones et al., 2014). Mental models elicited *in situ* consisted of more concepts, more linkages, and were more specific than those elicited in a more abstract environment (Jones et al., 2014). Therefore, presenting three novel examples of scientific information to fishers created an *in situ* environment where informal learning was stimulated prior to the interview.

To answer whether fishers' mental models were consistent regardless of their initial interest in a subject, they were questioned on the examples of scientific information that they found most and least interesting. Interviewees were not asked to rank their level of interest numerically, but simply to identify two articles from the three examples of scientific information presented: namely the one they found most and the one they found least interesting.

The interview was carried out in a conversational manner, although care was taken to cross-reference all the variables, to probe on the suspicion of a new variable, or clarify a lack of relationship between variables. When interviewees wandered off topic, or answered questions obscurely, they were also probed to clarify the nature of the relationship between the variables they were being questioned on. Each interview was voice recorded so that the mental models could be extrapolated at a later date. The interviews ran for an average of 15 minutes each.

The questionnaire was based on the dependent variable and the five variables identified in previous work with some modification (Chapters 3 & 4). For ease of interpretation during the interview, the variables' names were translated into simple English, and the affective variable was split in two (i.e. good and bad emotion) [Table 5.1].

Table 5.1 The variables as they are found in the literature, their expected positioning in the informal learning system, and their more participant-friendly translations.

Variable	Type of variable	Translation (standardised variable in FCM)
Willingness to uptake	Dependent	Level of interest (in learning more)
Cognitive	Independent	Clarity
Conative	Independent	Regular usefulness
Affective	Independent	Good & bad emotion
Investment in time	Independent	Investments of time
Investment in money	Independent	Investments of money

Fishers' FCM representations of mental models were extrapolated from voice recorded interviews and constructed using the FCM-based software Mental Modeler (see www.mentalmodeler.org (Gray et al., 2013b)) before being coded into a matrix where the degree of influence was coded according to Table 5.2 [Figures 5.1, 5.2] (Kosko 1986; Ozesmi and Ozesmi 2004; Gray et al., 2013b). Fishers were given individual code numbers and assigned an individual row each, while each possible interaction between variables in fishers' mental models was assigned an individual column. The quantitative influence values were then listed in the rows assigned to each individual fisher. After each FCM representation of fishers' mental models were coded into the matrix, variables were identified as transmitter (i.e. a variable that influences other variables but is not influenced by any other variables), receiver (i.e. a variable that is influenced by other variables, but does itself influence others), or ordinary variables (i.e. a variable that is both influenced by and influences others), and variable centrality was calculated using variables' outdegrees and indegrees.

	How much sense it...	Willingness to upt...	Regular usefulness	Good emotion	Bad emotion	Investment: time	Investment: money
How much sense i...		M+	M+	M+	L-	H+	H+
Willingness to upt...							
Regular usefulness				L+	L-	L+	L+
Good emotion		L+	L+			H+	M+
Bad emotion		M+				L-	L-
Investment: time			L+	L-	L+		L+
Investment: money		L-	M+	L-	L+		

Figure 5.1 Screenshot of an example matrix constructed using the Mental Modeler software, and coded as per Table 5.2.The rows indicate outgoing relationships, while the columns indicate incoming relationships. H = highly, M = moderately, L = low levels of effect. The positive and negative signs denote whether the effect was positive or negative i.e. H+ = Highly positive. See Table 5.2 for more detail.

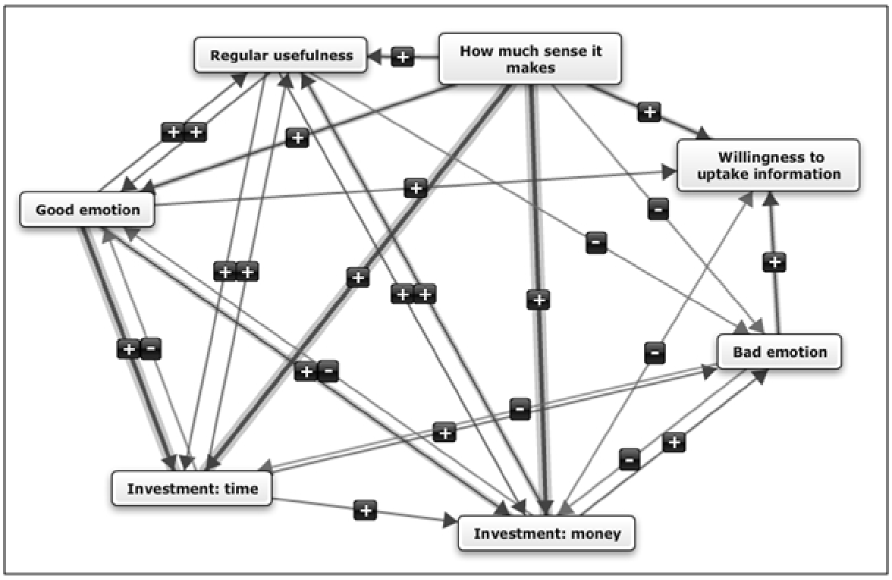

Figure 5.2 An example of a FCM representation of a fisher's mental model based on the matrix in Figure 5.1. The arrows denote the direction of each relationship, while the weight of each line and the symbol attached to each line denote the intensity of the relationship and its nature.

5.3.4 Using interview data to construct FCM representations of mental models

Fishers were interviewed once about the topic they found most interesting, and again about the topic they found least interesting. A matrix and, subsequently, a mental model was constructed for each topic fishers were interviewed about, resulting in two mental models per angler, and a total of 60 mental models for 30 fishers, 30 models based on what fishers found most interesting, and 30 based on what they found least interesting.

For each matrix/model, participants were asked about the relationships between each individual variable and all the others included in the matrix, with the exception of the dependent variable (i.e. level of interest in further informal learning). For example, fishers were asked how regular usefulness affected the importance of the clarity of the message, or the importance of good or bad emotion with respect to their willingness to informally learn more about the topic. When participants volunteered an interaction between their levels of interest in further informal learning and the independent variables, this was also recorded.

Participants were asked to rate the effect each variable had on the others using the scale presented in Table 5.2. The type of relationship was then assigned a quantitative value between -1 and +1 (i.e. -1 = very negatively, +1 = very positively).

Participants were also provided with a handout for their own reference, and to assist with the accuracy and consistency of their responses [Appendix D]. This handout first objectified the variables from Table 5.1 by, assigning otherwise abstract variables discrete, plain English names. The handout also anchored those variables by including definitions of each variable written in plain English, as well as a suggestion of how one might conceptually quantify that variable (Breakwell, 2001).

5.3.5 Data Analysis

Several methodological techniques were used to analyse each of the two cognitive maps generated from each fisher including:

(1) Evaluating mental model structure using variable type (to detect transmitter, receiver and ordinary variables), individual variable centrality (to illustrate differences in variables' relative importance to models based on topics fishers found most and least interesting), density (to compare the relative complexity of models based on topics fishers found most and least interesting), number of concepts and number of connections (both measures of complexity used to compare models based on topics fishers found most and least interesting), and frequencies of positive and negative indegree and outdegree (used to identify the nature of each variable's role in fishers' mental models and illustrate differences between variables' roles in models based on what fishers found most and least interesting).

(2) Compiling and comparing social FCM representations of mental models to gauge differences in fishers' thinking depending on interest level.

5.3.5.1 Evaluating individual model structure

For comparisons by interest level and topic, fishers' FCM representations of mental models were analysed using the following structural measures: (1) variable type (e.g. transmitter, receiver, ordinary) (2) individual variable centrality (3) density (4) number of concepts (5) number of connections.

Indegree, outdegree, centrality and density were calculated using formulae from previous studies (Ozesmi and Ozesmi, 2004; Nyaki et al., 2014). Outdegree is the cumulative strength of relationships exiting a variable (arrows pointing away from a variable). It is calculated by summing the absolute values of a variable’s outgoing influences. Indegree is the cumulative strength of relationships entering a variable (arrows pointing towards the variable). It is calculated by summing the absolute values of a variable’s incoming influences. The centrality of a variable reflects its relative importance to FCM representations of fishers’ mental models. The centrality is calculated by summing a variable’s indegree and outdegree (Ozesmi and Ozesmi, 2004).

Density was also calculated for each FCM representation of fishers’ mental models as a means to compare their relative complexity (Ozesmi and Ozesmi, 2004). It is calculated by dividing the total number of connections in each mental model by the number of possible connections. As density increases, a concept map is considered to be more highly connected, and suggests that interviewees see a large number of causal relationships among the variables (Ozesmi and Ozesmi, 2004). One-way ANOVA was used to compare the structural measures of fishers’ mental models between fishers’ levels of interest, and between topics within levels of interest. A Kruskal-Wallis test was used to compare the structural measures of fishers’ mental models within levels of interest because the sample sizes between topics varied considerably.

To understand whether the variables in fishers’ mental models related to one another in a predictable pattern, additional frequency metrics were used. Counting the frequencies of positive and negative indegree and outdegree for each variable (i.e. the number of positive and negative outgoing and incoming arrows) allowed the comparison of each variable’s influence (whether positive or negative) in FCM representations of fishers’ mental models. More traditional measures do not capture the nature of the relationships between variables to such a resolution. Furthermore, counting the frequencies of positive and negative indegree and outdegree for each variable makes it possible to see whether a variable’s influence changes dramatically depending on fishers’ levels of interest, or by the topic of the message.

5.3.5.2 Building social FCM representations of fishers’ mental models

In addition to the traditional structural metrics, social cognitive maps were created based on what fishers found most and least interesting. Aggregating many different cognitive maps has been shown to give a truer representation of a system. In the instance of this paper, creating social cognitive maps allows the scaling-up of individual knowledge to gauge what controls the level of interest the average fisher has in informal learning. One method of creating social cognitive maps is to additively superimpose individual cognitive maps (Ozesmi and Ozesmi, 2004). To do this, an augmented matrix was created including all models based on topics fishers found most interesting, and the same was done for models based on topics fishers found least interesting.

As per Ozesmi and Ozesmi (2004), it was assumed that all individual maps were equally valid, and therefore that each mental model was equally weighted. Therefore, an average was taken of the actual values for each existing relationship in the augmented matrix. Where the average fell outside of the values in Table 5.2, they were rounded to the nearest increment of 0.25. The final social models were drawn using the Mental Modeler software (Gray et al., 2013b).

Table 5.2 Levels of effect and their corresponding rating for input into the modelling interface of the Mental Modeler software (www.mentalmodeler.org).

Level of effect	**Code in matrix**	**Representation on resultant mental models**	**Numerical value assigned when coding for FCM Analysis**
Very positively	H+	+++	1
Moderately positively	M+	++	0.5
Slightly positively	L+	+	0.25
No effect		(no connection)	0
Slightly negatively	L-	-	-0.25
Moderately negatively	M-	--	-0.5
Very negatively	H-	---	-1

Several data analysis techniques were used, including: (1) Evaluating mental model structure using network structural metrics (2) evaluating the relationships between the variables using a non-traditional approach to network metrics (3) Compiling and comparing social FCM representations of mental models to gauge differences in fishers' thinking depending on interest level.

5.3.5.3 Gauging the relatedness and relative importance of variables using spring embedding

Using spring embedding to illustrate networks based on fishers' mental models gives more accurate insight into each variable's relative importance and importance to the network. Network analysis software packages such as Netdraw, which is part of the UCINET6 software package (Borgatti et al., 2002) are readily available, and make it possible to illustrate a network using spring embedding. Spring embedding is calculated based on similarities between variables. In networks calculated using spring embedding, variables with the most connections in common are represented as being closer together, whereas those that are the most different to other variables are represented as being further away. Correspondingly, the most well connected variables will tend to be in the centre of the network, while those with fewer or weaker connections will be on the periphery. Spring embedding therefore illustrates the relative importance of a variable to a network, and how similar it is to other variables (Borgatti, 2009; Cinner and Bodin, 2010).

Fishers' FCM representations of mental models were transcribed into a matrix to be input into UCINET6 before networks were drawn using Netdraw. Three sets of networks were drawn [Table 5.3]. For each level of interest, a network was drawn illustrating the total frequency of all existing relationships between variables regardless of their nature. These 'frequency' networks were drawn to illustrate levels of agreement between the FCM representations of fishers' mental models. As network analysis matrices do not allow for positive and negative values, it was therefore necessary to construct separate networks for the positive and negative relationships from each FCM representation of fishers' mental models. Hence, the second and third sets of networks were based on the intensity (i.e. the sum of absolute values) of positive and negative relationships between variables.

Table 5.3 List of networks constructed based on the FCM representations of fishers' mental models.

Fishers' FCMs	**Most interested**	**Least interested**
Networks constructed	Frequency	Frequency
	Positive intensity	Positive intensity
	Negative intensity	Negative intensity

In the context of the FCM representations of mental models illustrating fishers' informal learning, spring embedding illustrates how closely variables are related to one another with respect to dictating fishers' interest in a topic. More specifically, the frequency networks highlight those variables that stand apart and are less likely to be influenced by the others, while the positive and negative intensity networks illustrate the likelihood of each variable affecting others, or being affected itself in a positive or negative way.

Calculating node sizes by Eigenvector provides further information about fishers' informal learning. Since Eigenvector is a measure of connectedness, it is possible to gauge how influential a variable might be on other variables despite appearing to be quite distant in the network [Figure 5.3]. The Eigenvector provides information about variables that might not have the strongest ties with its immediate neighbours, but might connect variables with highly localised connections to other variables that are more distant. The Eigenvector therefore makes it possible to identify variables that might superficially appear to be quite distant from others, but are closer to, and therefore have greater potential to influence, a large number of variables from across the network as a whole (Borgatti and Everett, 1997; Hanneman and Riddle, 2005).

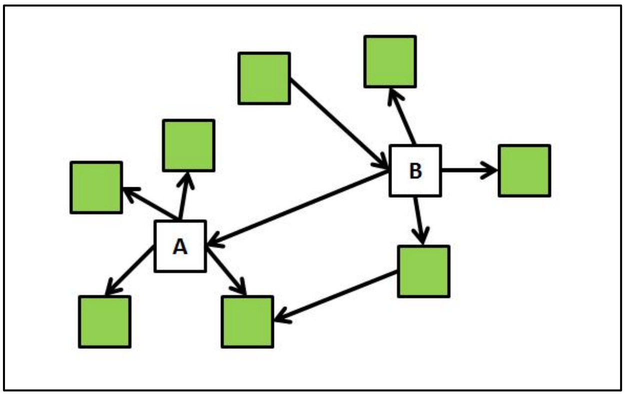

Figure 5.3 Hypothetical network showing the relationships between variables A and B and a host of other variables. It is possible for variable B to have a higher Eigenvector than variable A, despite the fact that it appears to be further away from other variables than variable A. In this hypothetical network, variable B is connected to more variables that are fairly distant from the close-knit grouping that variable A is part of. Therefore, variable B is related to, and can influence more variables across the entire network than variable A.

To ensure the Eigenvectors compared between nodes were significantly different than random, a modified bootstrap approach was used. The Eigenvectors of the variables from the observed networks were checked against those from a sample of 10,000 random networks with an identical number of nodes and densities. A Welch's twin-tailed T-test was then run ($P<0.05$) to confirm that the Eigenvectors of the variables in the observed networks were significantly different from random. These analyses were done using the R statistical package v. 3.2.0 and the "*igraph*" library (Csardi and Nepusz, 2006; R Development Core Team, 2014).

5.4 Results

5.4.1 Comparison of FCM representations of fishers' mental models by level of interest in fisheries related information

Comparison of fishers' individual cognitive maps based on traditional structural metrics, indicated that maps based on topics fishers found most interesting had significantly higher numbers of variables (all inclusive), and also a greater numbers of connections between the variables, resulting in significantly higher densities [Table 5.4]. Models based on topics fishers found least interesting included significantly more transmitter variables than those models based on topics fishers initially found most interesting [Table 5.4]. However, having significantly more transmitter variables was largely due to the simplistic nature of those models precluding the existence of more complex relationships between the constituent variables.

Table 5.4 Comparison of structural measures between models based on examples of scientific information fishers found most and least interesting using a single factor ANOVA (significant at P<0.10).

Structural measurement	Most Interesting N=30 Mean ± SD	Least Interesting N=29 Mean ± SD	F	df	P
No. variables	6.7 ± 0.9	3.2 ± 0.9	238.18	1	<0.001
No. transmitters	0.5 ± 0.9	1.5 ± 0.7	21.021	1	<0.001
No. receivers	1.2 ± 0.6	1.1 ± 0.4	0.199	1	0.657
No. ordinary	5.9 ± 1.4	0.6 ± 0.8	204.432	1	<0.001
No. connections	18.0 ± 6.9	2.6 ± 1.7	138.674	1	<0.001
Density	0.4 ± 0.1	0.2 ± 0.1	39.25	1	<0.001

5.4.2 Comparison of models by article subject matter

Subject matter had a significant effect on the number of variables (i.e. the number of variables included in cognitive maps based on the mackerel diet study was higher than those based on the other studies), but had no effect on the other structural measures of fishers' cognitive maps if they considered the topic to be most interesting [Table 5.5]. In terms of the articles that fishers found to be least interesting, the models derived from the mackerel diet study differed from models based on the other topics by number of variables, number of receiver variables, number of ordinary variables, number of connections and overall density [Table 5.6]. However, there was no significant difference between models derived from the shark tracking study or anti-angling philosophy study [Table 5.6]. Fishers who found the shark tracking study least interesting generated cognitive maps that were significantly less dense than those based on the other topics [Table 5.6].

Table 5.5 Table comparing the structural measures of models based on topics recreational fishers found most interesting using a Kruskal-Wallis test (significant at P<0.10).

Structural measurement	**Shark tracking study (cognitive)** N=9 Mean ± SD	**Mackerel diet study (conative)** N=4 Mean ± SD	**Anti-angling philosophy study (affective)** N=17 Mean ± SD	Adjusted H	df	P
No. variables	6.5 ± 0.6	7.0 ± 0.3	6.1 ± 1.5	6.249	2	0.044
No. transmitters	0.5 ± 0.6	0.5 ± 1.0	0.6 ± 0.9	0.517	2	0.772
No. receivers	1.25 ± 0.5	1.1 ± 0.6	1.4 ± 0.7	0.551	2	0.759
No. ordinary	4.8 ± 1.0	5.4 ± 1.0	4.1 ± 2.1	4.516	2	0.105
No. connections	16.8 ± 7.8	20.0 ± 5.7	14.3 ± 7.9	3.137	2	0.208
Density	0.5 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	2.293	2	0.318

Table 5.6 Table comparing the structural measures of models based on topics recreational fishers found least interesting using a Kruskal-Wallis test (significant at P<0.10).

Structural measurement	**Shark tracking study (Cognitive)** N=13 Mean ± SD	**Mackerel diet study (Conative)** N=3 Mean ± SD	**Anti-angling philosophy study (Affective)** N=13 Mean ± SD	Adjusted H	df	P
No. variables	2.9 ± 0.8	4.7 ± 0.6	3.2 ± 0.7	10.296	2	0.006
No. transmitters	1.4 ± 0.5	1.3 ± 0.6	1.7 ± 0.9	1.419	2	0.492
No. receivers	1.1 ± 0.3	1.7 ± 1.2	1.1 ± 0.3	6.142	2	0.046
No. ordinary	0.5 ± 0.5	1.7 ± 1.2	0.4 ± 0.9	8.958	2	0.011

No. connections	2.0 ± 0.8	5.3 ± 2.5	2.6 ± 1.6	8.767	2	0.012
Density	0.2 ± 0.04	0.3 ± 0.1	0.4 ± 0.1	16.612	2	<0.001

5.4.3 Centrality of variables

The traditional way of measuring the relative weight or "importance" of each variable to the models is by calculating each variable's centrality value. Clarity, regular usefulness and investments in time have the highest centrality values outside of the dependent variable in both models based on topics fishers found most interesting and models based on what they found least interesting [Table 5.7]. The dependent variable 'level of interest' had a low centrality value compared to the aforementioned variables in models based on what fishers found most interesting [Table 5.7]. The dependent variable's low centrality in this instance does not necessarily indicate a lack of importance. Rather, when fishers' interest is high, the independent variables interact more closely with each other than they do with fishers' levels of interest. As such, few of the tested variables directly influence fishers' interest in new information when they have decided that it is interesting, perhaps indicating a sophisticated thought process.

Table 5.7 Relative centrality values of variables from fishers' mental models ranked in descending order. Indegree describes instances where external variables are effecting the subject variable. Outdegree describes instances where the subject variable is effecting external variables.

Variables by descending centrality	Indegree	Outdegree	Centrality
Models based on examples of scientific information fishers found most interesting (N=30)			
Clarity	1.2	2.5	3.7
Regular usefulness	1.4	2.2	3.6
Investment: time	2.0	1.1	3.1
Good emotion	1.2	1.9	3.0
Investment: money	1.5	1.2	2.7
Level of interest	2.0	0.1	2.1
Bad emotion	0.6	1.1	1.7
Models based on examples of scientific information fishers found least interesting N=(29)			
Regular usefulness	0.4	0.7	1.1
Level of interest	0.9	0.0	0.9
Clarity	0.1	0.8	0.9
Bad emotion	0.1	0.2	0.2
Investment: time	0.1	0.1	0.2
Good emotion	0.0	0.1	0.1
Investment: money	0.0	0.1	0.1

5.4.4 Relationships between variables

Counting the average number of outgoing vectors for each variable and sorting them by their positive or negative nature gave more insight into fishers' informal learning needs. For example, Table 5.8 indicated that variables such as the clarity of the information, the perceived regular usefulness of the information and levels of good emotion attached to the new information all interacted and cumulatively had the greatest positive influence on other variables in their mental models. Levels of bad emotion and investments in time and money however, had the largest negative effects on other variables in fishers' mental models, suggesting that these variables together might have acted as constraints to fishers' informal learning [Table 5.8].

While traditional indegree and outdegree measures are informative (i.e. Table 5.7), segregating incoming and outgoing vectors by their positive or negative nature has the potential to provide additional insights into fishers' informal learning. The traditional indegree measure gave insights into the nature of investments in time as a variable in fishers' informal learning models. Investments in time had the highest average indegree of all the variables, suggesting that while it might have acted as a constraint, that constraint could be mitigated or negated by a number of external variables [Table 5.7]. Segregating the incoming and outgoing vectors provided further insight into how investments in time were influenced by other variables. Investments in time had the potential to be positively influenced by more variables than even fishers' levels of interest [Table 5.8]. It becomes apparent, therefore, that the amount of time fishers invest into the new information is not necessarily reflective of their interest alone.

Table 5.8 Average outdegree of variables included in fishers' mental models segregated by their positive or negative natures. Variables were not listed if their average outdegree was <0.1. Indegree describes instances where external variables are effecting the subject variable. Outdegree describes instances where the subject variable is effecting external variables.

Variables by descending no. outgoing vectors	Average outdegree	Standard deviation
***Variables from models based on examples respondents were most interested in* (N=30)**		
Positive		
Clarity	3.6	1.4
Regular usefulness	3.5	1.7
Good emotion	3.2	1.6
Investment: money	1.4	1.3

Investment: time	1.4	1.5
Bad emotion	0.5	0.9
Level of interest	0.3	0.1
Negative		
Bad emotion	1.5	1.5
Investment: time	1.2	1.3
Investment: money	0.9	0.8
Regular usefulness	0.1	0.3
Clarity	0.1	0.4
***Variables from models based on examples respondents were least interested in* (N=29)**		
Positive		
Regular usefulness	0.9	0.7
Clarity	0.9	0.9
Investment: time	0.1	0.4
Negative		
Bad emotion	0.4	0.4
Investment: time	0.3	0.3
Investment: money	0.1	0.2
Clarity	0.1	0.2

Notably, of the three variables with the highest average number of outgoing vectors (i.e. the clarity of the message, regular usefulness and good emotion), regular usefulness had the higher number of variables positively affecting it [Tables 5.8, 5.9]. Since regular usefulness also appeared to have a relatively low number of negative incoming vectors, it would seem that the perceived regular usefulness of a piece of information was more resilient and therefore more likely to influence fishers' interest in new information than the message's clarity or any good emotion attached to that information [Table 5.9]. In this instance, traditional structural measures were shown to be less informative, as they failed to cater for the positive/negative nature of the relationships between variables and lost out on resolution.

Table 5.9 Ranked average indegree to variables from fishers' mental models segregated by their positive or negative nature. Variables were not listed if their average indegree was <0.1.

Variables by descending no. incoming vectors	Average indegree	Standard deviation
***Variables from models based on examples respondents were most interested in* (N=30)**		
Positive		
Investment: time	2.9	1.4
Level of interest	2.8	1.0
Regular usefulness	2.0	1.2
Investment: money	2.0	1.6
Good emotion	1.6	0.9
Clarity	1.2	1.8
Bad emotion	0.9	1.0
Negative		
Investment: money	0.8	0.7
Level of interest	0.8	0.8
Good emotion	0.7	0.8
Investment: time	0.5	0.7
Clarity	0.3	0.6

Regular usefulness	0.3	0.6
Bad emotion	0.3	0.8
***Variables from models based on examples respondents were least interested in* (N=29)**		
Positive		
Level of interest	1.4	0.5
Regular usefulness	0.5	0.7
Clarity	0.2	0.5
Investment: time	0.1	0.2
Negative		
Level of interest	0.6	0.7
Bad emotion	0.1	0.2
Good emotion	0.1	0.0

5.4.5 Social Cognitive Maps

Beyond the differences in density between the two average social models (Ozesmi and Ozesmi 2004), their construction gave more information about the interactions between the component variables [Figures 5.4, 5.5]. Firstly, while bad emotion did not interact directly with fishers' levels of interest in topics they found most interesting, it had a direct influence on their levels of interest when they found the topic less/least interesting [Figures 5.4, 5.5]. Secondly, even when topics were considered most interesting, an investment in money was the only variable that directly negatively influenced fishers' levels of interest in the topic [Figure 5.4]. Thirdly, clarity, regular usefulness and good emotion were the only variables to have direct, positive relationships with fishers' levels of interest in topics they found most interesting [Figure 5.4]. Lastly, investments in time acted as a receiver variable in the social model based on what fishers found most interesting [Figure 5.4]. Investments in time were clearly important in the structure of this model, but did not directly influence any other variables.

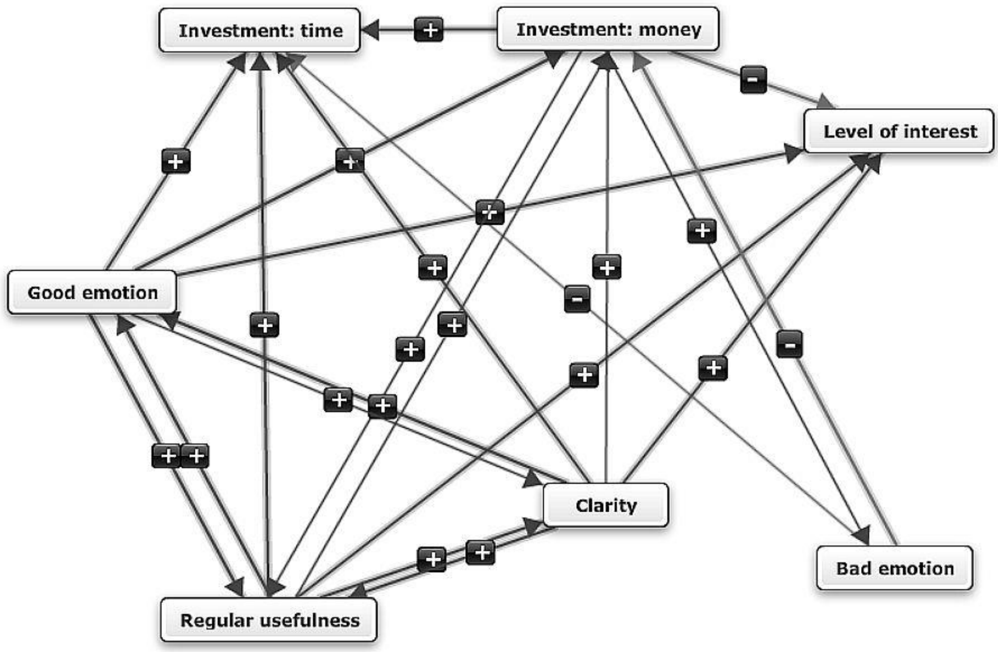

Figure 5.4 Results of averaged 'social cognitive map' based on topics fishers found most interesting (N=30). The directionality of each relationship is indicated by the arrowheads. The intensity of each relationship is indicated by the thickness of the line. The positive or negative nature of each relationship is indicated by the symbol assigned to each line.

However, it is important to remember that while these models provide valuable insights into how the component variables relate to one another, they are average models, and should not be treated as a representation of any individual fisher. The relationships illustrated in Figures 5.4 and 5.5 must be interpreted as general trends, and only two examples of the potential models within the standard deviations listed in Tables 5.8 and 5.9.

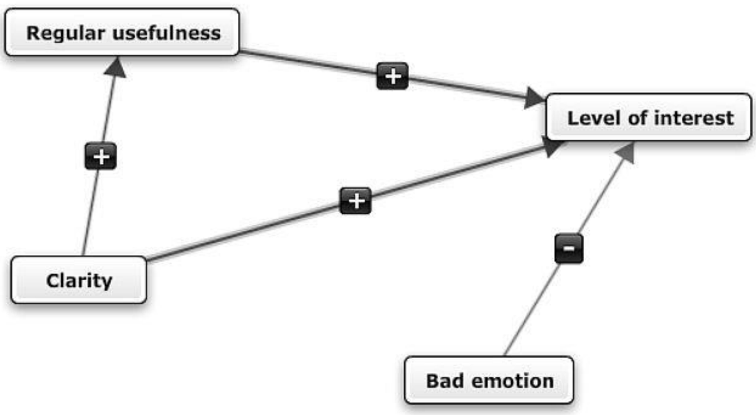

Figure 5.5 Results of averaged 'social cognitive map' based on topics fishers found least interesting (N=29). The directionality of each relationship is indicated by the arrowheads. The intensity of each relationship is indicated by the thickness of the line. The positive or negative nature of each relationship is indicated by the symbol assigned to each line.

5.4.6 *Using spring embedding and Eigenvector to investigate the relative importance of variables*

The Eigenvectors of the variables discussed in the following sections were significantly different than random [Table 5.10] (i.e. the effect that each variable had on the network as a whole was significantly different than what would be expected from variables in random networks with similar numbers of variables and densities).

Table 5.10 Results of two-sample Welch's T-tests checking Eigenvectors of variables from observed networks against random networks with an identical number of variables and identical densities to the observed networks using a bootstrap approach (N=10,000, significant at P<0.05).

Observed Networks	df	t	P
Networks based on fishers' 'most interested' mental models			
Frequency of all relationships	9999	-85.15	<0.001
Intensity of positive relationships	9999	41.7	<0.001
Intensity of negative relationships	9999	-7.43	<0.001
Networks based on fishers' 'least interested' mental models			
Frequency of all relationships	9999	-37.85	<0.001
Intensity of positive relationships	9999	-46.36	<0.001
Intensity of negative relationships	9999	-159.29	<0.001

5.4.6.1 *'Most interested' models*

The following section builds upon the previous through the use of network analysis. Illustrating networks using spring embedding and centrality measures such as the Eigenvector allows better representation of the strength and nature of relationships between the variables used in the FCM representations of fishers' mental models.

The fairly uniform tie strengths in Figure 5.6 indicate a high degree of agreement on the presence of relationships between the variables in the network. Node size, dictated by Eigenvector, is also fairly uniform in this network, indicating that the variables present are equally well linked to other well-networked variables [Figure 5.6]. This network also highlights how investments of money are very closely related to the perceived regular usefulness of the information.

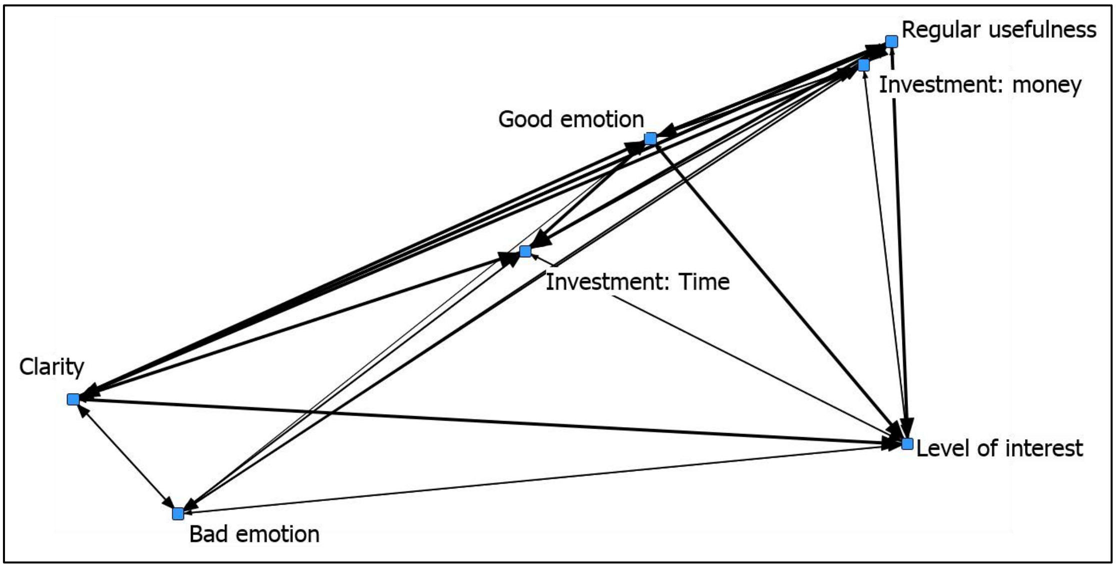

Figure 5.6 Network illustrating the frequency of all existing relationships (positive and negative) between variables in FCM representations of fishers' 'most interested' mental models (N=30). The node sizes are indicative of the Eigenvector in this network i.e. The higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

The network represented in Figure 5.7 shows that regular usefulness, clarity, good emotion and investments in time and money are the most tightly related variables (i.e. they share many common relationships with other variables). The close proximity of regular usefulness, clarity and good emotion also indicate a degree of similarity between these variables in terms of the way they relate to other variables [Figure 5.7]. The high Eigenvectors of regular usefulness, clarity, good emotion, levels of interest and investments of time and money indicate that these variables are well connected to other highly networked variables [Figure 5.7]. The extensive networking between these variables suggests that when fishers are interested in a topic, positive outdegree can arise from a number of variables, and no one variable is necessarily any more important than the others as a source of positive influence. While it appears from this network that an investment in time would have strongly positive effects on the other variables, this appearance is misleading. According to the interviews, most fishers stated that they would make more effort to find a use for and make sense of the information were they to have invested time into the information in the first instance. Bad emotion has the least number of positive relationships with any other variables when fishers are interested in a topic, and therefore it sits apart from them in the network.

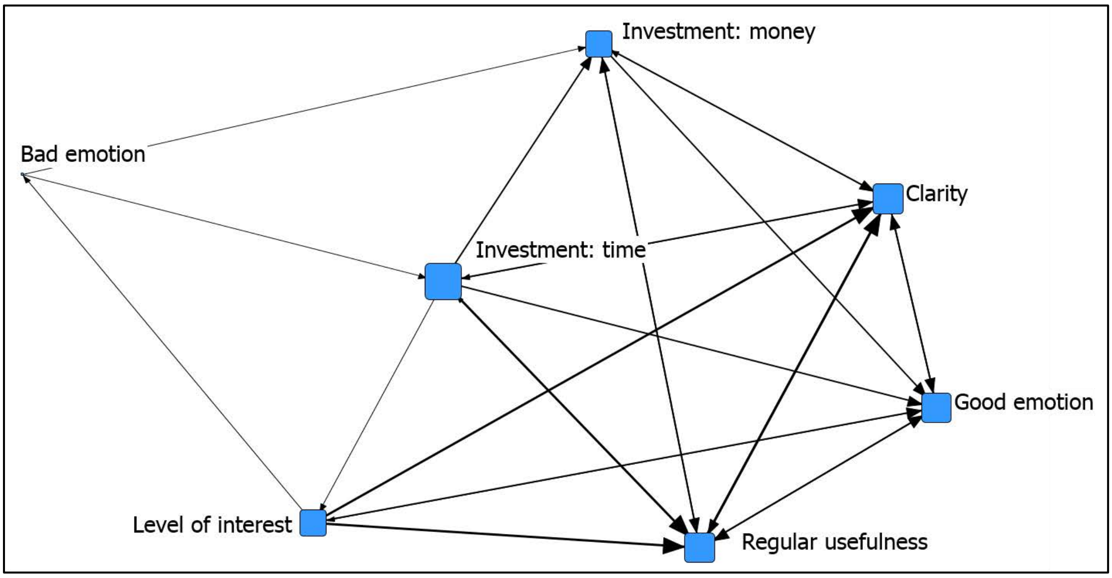

Figure 5.7 Network illustrating the intensity of positive relationships (i.e. the sum of all positive relationships coded using Table 5.2) between variables in the FCM representations of fishers' 'most interested' mental models (N=30).The node sizes are indicative of the Eigenvector in this network i.e. The higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

In the network portrayed in Figure 5.8, bad emotion has the highest Eigenvector, indicating that it negatively affects the largest number of influential variables. The strength of the ties between investments of time and money and bad emotion also indicate that these two variables are affected the most negatively by bad emotion [Figure 5.8]. The fact that clarity, good emotion and regular usefulness have very small Eigenvectors in this network indicate how unlikely it would be for these three variables to have a negative impact on fishers' interest in informal learning [Figure 5.8].

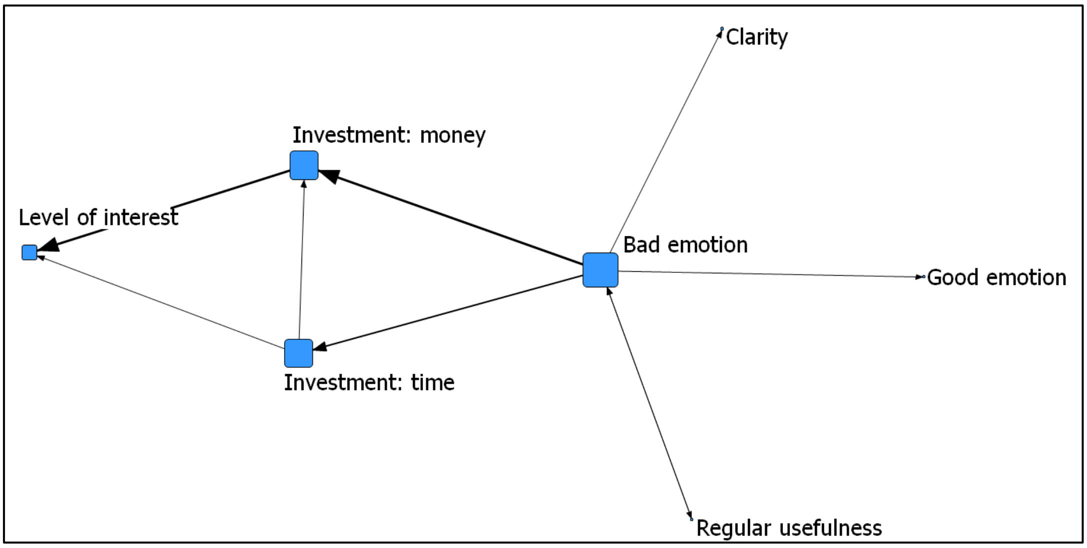

Figure 5.8 Network illustrating the intensity of negative relationships (i.e. the sum of the absolute values of fishers' negative relationships between variables) between variables in FCM representations of fishers 'most interested' mental models (N=30). The node sizes are indicative of the Eigenvector in this network i.e. the higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

5.4.6.2 'Least interested' models

The very uneven Eigenvector values and weak ties between variables in Figure 5.9 are indicative of substantial differences between fishers' 'least interested' FCMs. The relatively low levels of agreement between the FCM representations of fishers' 'least interested' mental models are largely due to how simplistic these models are compared to fishers' highly complex 'most interested' models. Regular usefulness and investments in time have the highest Eigenvector in this network, indicating that they have great influence over other variables, even when fishers find something less interesting [Figure 5.9]. These two variables are also placed very closely together in this network, indicating high levels of similarity between the two.

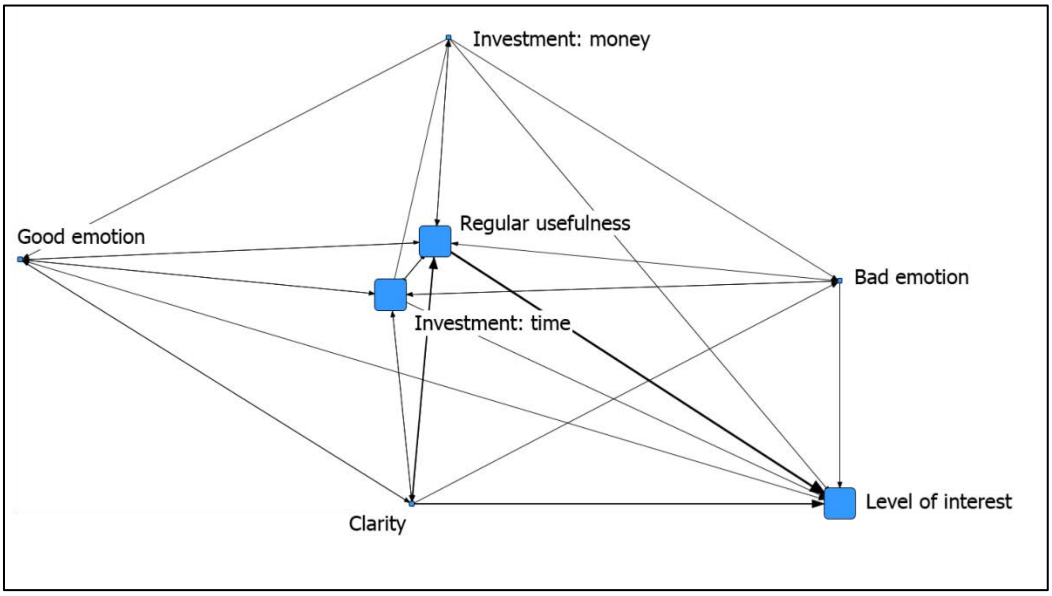

Figure 5.9 Network illustrating the frequency of all (positive and negative) relationships between variables in FCM representations of fishers' 'least interested' mental models (N=29). The node sizes are indicative of the Eigenvector in this network i.e. The higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

Figure 5.10 illustrates positive relationships in fishers' 'least interested' mental models. There is less complexity in this network than in fishers' 'most interested' mental models (i.e. Figure 5.7) indicating comparatively less resilience among the variables in fishers' 'least interested' mental models. However, regular usefulness takes a more central position in this network, and has the strongest connection with fishers' levels of interest. The relative importance of regular usefulness in fishers' 'least interested' models indicates that it might become more important to appeal to fishers' sense of how regularly useful a piece of information could be as their interest levels drop.

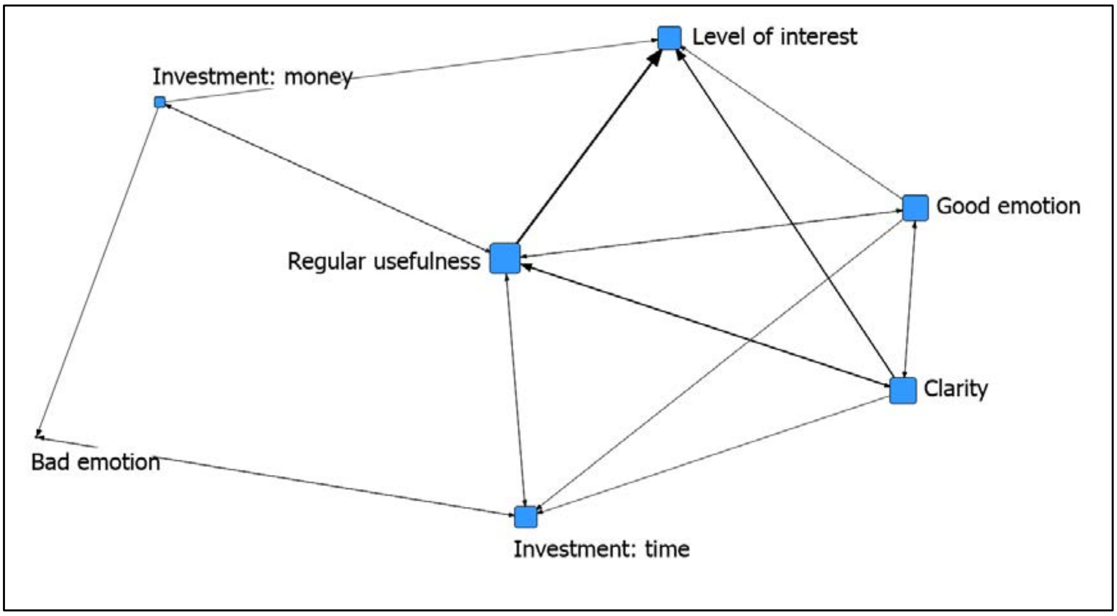

Figure 5.10 Network illustrating the intensity of positive relationships (i.e. the sum of all positive relationships coded using Table 5.2) between variables in FCM representations of fishers' 'least interested' mental models (N=29).The node sizes are indicative of the Eigenvector in this network i.e. the higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

Although the ties in the network illustrated in Figure 5.11 are relatively weak, they still suggest that investments of money and time are often related to each other and, correspondingly, levels of good emotion [Figure 5.11]. In this network, bad emotion is not related to any other variables aside from level of interest [Figure 5.11]. The isolation of bad emotion suggests that while bad emotions can drop fishers' levels of interest when levels of interest are already low, fishers' bad emotions are themselves unlikely to be influenced by other variables in these circumstances [Figure 5.11].

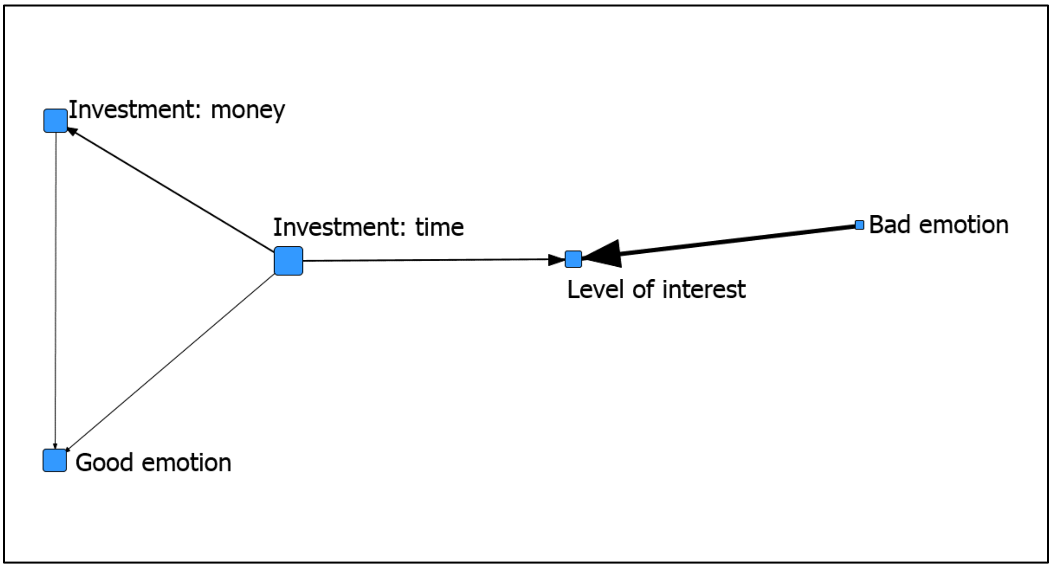

Figure 5.11 Network illustrating the intensity of negative relationships (i.e. the sum of the absolute values of fishers' negative relationships between variables) in FCM representations of fishers' 'least interested' mental models (N=29). The node sizes are indicative of the Eigenvector in this network i.e. the higher the Eigenvector, the larger the node. The arrows denote the directionality of relationships between the variables, and their line thickness reflects the strength of that relationship.

5.5 Discussion

This chapter has important implications for the communication of scientific information to recreational fishers, the understanding of informal learning, and the applications for and analyses of data gathered using the FCM approach. The results of this chapter suggest that fishers' initial levels of interest in a topic can have significant effects on how their interest in learning more about that topic might be stimulated, and the complexity of the thought processes involved in making a decision to learn more about a particular topic. Furthermore, results indicate that the topic itself has no significant effect on whether a fisher is likely to seek more information on that topic, meaning that fishers' levels of interest are a better indicator of their willingness to informally learn a piece of scientific information. This chapter also identifies a number of variables important for motivating the informal learning of scientific information in fishers. In addition, the patterns identified in this chapter align with existing mass communication frameworks. However, the application of non-traditional measures (i.e. positive and negative indegree and outdegree) and network analysis give further insight into what might improve the communication of scientific information to fishers more effectively than the existing frameworks.

Recreational fishers' levels of interest in a topic significantly affected the thought processes contributing to their interest in further informal learning. The models based on topics fishers were most interested in were significantly more complex than those based on topics they were least interested in, to the point where the dependent variable, 'level of interest', had a lower centrality score than five of the independent variables (i.e. clarity, regular usefulness, investments of time, good emotion and investments of money). This finding, along with the simplicity of the models based on topics fishers were least interested in and the relative importance of the clarity of the information and its regular usefulness in both models (based on topics fishers found most and least interesting), give insight into how fishers' thought processes evolve as they assess pieces of scientific information. These two findings suggest that it is more likely that fishers think more deeply about what makes a topic interesting after initially deciding that it is interesting, rather than the alternative scenario where a topic needs to fulfil a relatively large number of criteria before being considered interesting. However, there is also the possibility that the models based on what fishers found least interesting might represent the most basic criteria that need to be satisfied before further thought is expended on the matter.

With one exception, topic itself did not significantly affect recreational fishers' interest in further informal learning. The results of this study indicate that the complexity of fishers' mental models was affected most significantly by their initial interest levels regardless of the subject matter. The relationships between the key variables in fishers' mental models were fairly consistent depending on their initial levels of interest, with the subject matter of the excerpt presented having little effect. However, the mackerel diet study did significantly affect several structural measures of fishers' cognitive maps whether they chose the study to be most or least interesting. This effect might be partly explained by the fact that the familiarity of the subject matter made it easier for fishers to engage with the information before deciding that it was the least interesting of the three examples. Also, the size of the effects that the mackerel diet study had on fishers' cognitive maps were small compared to those caused by their initial interest levels. Additionally, the mackerel diet study's effects were most evident when fishers' cognitive maps were most simplistic (i.e. when they deemed the topic to be least interesting). Therefore, it would appear that while fishers might engage with some subject matter differently than others, their initial levels of interest in that information are far better indicators of their willingness to informally learn more about a piece of information.

Several recommendations based on the results of this chapter could improve communication efforts aimed at recreational fishers. Communicators should ensure that their messages are clear and easily understood by the target audience without requiring further investigation or education on their part. An atmosphere of positive emotion should be fostered, and negative emotion minimised. The minimisation of negative emotion can be difficult in fisheries, as increasingly, messages from management agencies are about limiting recreational fishers' behaviour (e.g. limiting take, by-catch or effort) (Smith et al., 1999; Kaplan and McCay, 2004; McPhee, 2008). While messaging like this is often used to give a sense of urgency to the message, the results of this chapter and other studies indicate that negative emotion is likely to constrain fishers' interest in informally learning more (Smith et al., 1999). Finding ways to instigate behaviour change through positive messaging is far more likely to meet with success, e.g. by giving fishers a sense of stewardship, or recognising their existing environmental efforts etc. (Granek et al., 2005; Granek et al., 2008). Lastly, it is important to make the new information appear regularly useful to the target audience. This last variable is positively influenced by many others, making it less likely to be compromised once the fishers' perceive a regular use for the information. However, regular usefulness and clarity are also the only variables likely to raise fishers' interest in a topic if their initial appraisal of the messaging is indifferent.

While the mental models generated from fishers in this chapter varied slightly between individuals, the relationships between the key variables remained relatively consistent. Additionally, the fishers sampled did not feel additional variables external to those provided were necessary to explain their thought processes. The clarity of the message (i.e. the cognitive dimension), the regular usefulness (i.e. the conative dimension), and an emotional component (i.e. the affective dimension) remained highly influential. The prominence of these three variables is very much in line with Alsop's Informal Conceptual Change model, discussed in Chapter Three and the findings of Chapter Four, that verified the potential importance of these variables in several fisheries stakeholder groups (i.e. fisheries managers, researchers and commercial and recreational fishers) (Alsop, 1999; Li, 2015). The analysis of the positive relationships in FCM representations of fishers' 'most interested' mental models further confirmed the tight relationships between these three variables.

The findings of this chapter also align well with existing frameworks for mass communication aimed at changing behaviour. Of these frameworks, TORE™ is among the best known. The TORE™ framework has been used to improve conservation behaviour and awareness, and increase tourists' willingness to donate towards conservation efforts, among other things (Weiler and Ham, 2002; Powell and Ham, 2008). TORE™ stresses the importance of four key criteria: a strong, coherent theme aimed at a specific behaviour; an organised message that is easy for the audience to uptake; a message that is relevant to the audience; and a message that is enjoyable to the audience (Powell and Ham, 2008; Ham, 2013). This chapter's findings that the clarity of the information, its perceived regular usefulness and good emotions associated with the information influence fishers' interest in informal learning most strongly resonates strongly with this framework. The clarity of the information is interchangeable with the organisation of the message, in that improved clarity enables fishers to understand the message, and ultimately the message's theme, more clearly (Ham et al., 1993; Ross et al., 2003; Ward and Wilkinson, 2006). The organisation of the message also involves minimising the amount of time and money the audience needs to invest in taking up the information (Ham, 2013). In the models presented in this chapter, the perceived usefulness of the information fulfils the criteria of relevance as the fishers were relating the new information with their own activities. How enjoyable the message is to fishers is addressed by the good emotions fishers associate with the new information. However, using 'good emotions' as a variable also captures other factors aside from how enjoyable the message is, including fishers' previous relationships with the type(s), source(s), or implications of the new information. This chapter's results suggest that frameworks with these four criteria at their core would be suitable for guiding communication of scientific information to recreational fishers. The congruence of this chapter's results with existing literature and proven frameworks adds weight to the findings, and further confirms that a model derived from informal learning literature can be applied to better understand informal learning in recreational fishers.

While the research in this chapter was exploratory, and employed novel, previously untested, techniques for analysing mental models, it has shown promise, and offers more resolution than existing frameworks used to understand informal learning and structure mass communication efforts (Alsop, 1999; Ross et al., 2003; Ward and Wilkinson, 2006; Ham, 2013). Applying less traditional methods of analysis to FCM and network data such as sorting indegrees and outdegrees by whether they are positive or negative yielded valuable insights into data of this nature that would be otherwise obscured when using more traditional measures. Specifically, the ability to more closely examine the degree to which certain variables had a positive or a negative effect on external variables, and how susceptible they might be to positive/negative influences from other variables.

This study established that the FCM approach can be used to model thought processes influencing fishers' interest in informal learning. Despite its exploratory nature, several interesting patterns warranting future investigation were also revealed during this chapter. Firstly, it was apparent that the relative importance of certain variables changed depending on fishers' levels of interest, as did the way they related to other variables. Investigating whether there are predictable patterns to these changes could prove invaluable for communicators (i.e. they could then predict fishers' expectations/perceptions of a piece of information and tailor their efforts to suit). Understanding the changes that can occur due to an individual's interest level also has major implications for those researchers investigating decision models. If there were changes to the relative importance of the variables investigated in this chapter, and their relationships, there is a possibility that the same situation might exist in other contexts where individuals are asked to model a system using an FCM approach.

Secondly, while the models derived in this chapter can be used to make suggestions on how communication to recreational fishers can be improved, and are highly congruent with existing communication frameworks, it would be valuable to test whether these models reflect reality by constructing communication programs based on them and measuring their successes/failures (i.e. whether fishers' uptake of scientific information was improved). In particular, it would be interesting to investigate whether it is possible to 'stimulate' a fishers' interest in informal learning despite an initial lack of interest in the topic. Of interest also would be whether different fisheries stakeholders have different models, with different key variables, and different relationships between them. Evidence suggests that investments in time and money can also constrain informal learning in natural resource managers (Cvitanovic et al., 2014). However, thus far, no one has demonstrated the extent to which these variables constrain their informal learning activities, nor investigated the presence of any drivers that might override the effects of these constraints. Clearly, much further research is needed before informal learning among fisheries stakeholders can be confidently and strategically addressed.

The results of this study also suggest that the understanding (and execution) of scientific outreach aimed at fisheries stakeholders might benefit from the application of mental modelling techniques that elicit more complex, nuanced models. Multiple qualitative and quantitative mental modelling approaches have been used extensively to model participants' understandings of systems external to themselves (e.g. the ecology of fish they target as fishers, problem solving in institutions, work hazards etc.) (Breakwell, 2001; Johnson-Laird, 2001; Kolkman et al., 2005; Lindern, 2010; Jones et al., 2011; Gray et al., 2012; Lynam et al., 2012; Gray et al., 2013a; Gray et al., 2014; Jones et al., 2014). This study shows that it is possible to consistently elicit detailed mental models of a highly individualistic and internal system such as informal learning using an FCM approach. Therefore, more qualitative mental modelling techniques might also be applicable to modelling fisheries stakeholders' informal learning of scientific information. Future studies and communication efforts are likely to benefit from the gathering of more nuanced information about the relationships between the component variables affecting the informal learning of scientific information by fisheries stakeholders.

This study provides valuable direction for future attempts to model informal learning in fisheries stakeholders. The consistency of the structural measures between fishers' mental models irrespective of their topics indicates that the approach taken in this study, and the variables that have been identified, could be used to model fishers' willingness to informally learn across a range of subjects. However, further studies using larger sample sizes will be necessary before a final list of variables driving and constraining fishers' interest in informal learning can be arrived upon. Upon finalising a list of variables, large-scale, structured quantitative surveys targeted at a wider sector of the recreational fisher community could be used to more accurately quantify the relationships in fishers' informal learning models. The findings from these surveys could then potentially be used to create a FCM representation of a community mental model, such as in Gray et al.'s study in 2012, where several stakeholder groups' cognitions of the Atlantic Summer Flounder fishery were combined to create an FCM representation of their integrated knowledge (Gray et al., 2012). Additionally, smaller scale studies employing more qualitative mental modelling approaches are also likely to contribute greatly towards the understanding of the exact nature of the relationships between the variables effecting fisheries stakeholders' informal learning of scientific information. However, should management agencies be more interested in eliciting less detailed mental models quickly, the variables identified in this study, and the methodologies developed here, represent an important first step for studies into the communication of scientific information to stakeholders in a fisheries context, and should be sufficient for the efficient generation of mental models aimed at informing outreach strategies.

5.6 Conclusion

This chapter demonstrated the applicability of variables identified in Chapter Three and verified in Chapter Four to modelling thought processes contributing to recreational fishers' willingness to informally learn scientific information. Further work is necessary to establish the applicability of these variables to fisheries managers, researchers and commercial fishers, and to identify the presence of any variables that may be exclusive to those stakeholder groups. Though this chapter has focused only on recreational fishers, it has resulted in the development of a methodology that is likely to be applicable to the other stakeholder groups and, if correctly applied, is unlikely to result in any loss of resolution, or overlooking of novel variables. In the context of the overall aim of this thesis (i.e. the development of a theory-based, useable model of fisheries stakeholders' informal learning of scientific information), this chapter has shown that informal learning theory is applicable to fisheries stakeholders' informal learning of scientific information, and also demonstrated the construction of useable, high resolution mental models that could be used to construct communication strategies aimed at fisheries stakeholders. Moreover, this chapter demonstrates the ability of the FCM approach and network analysis techniques to map and rigorously analyse the complex interactions between the constituent variables in stakeholders' mental models. The following chapter looks for avenues to maximise the efficiency of communication strategies developed based on the findings of this chapter, and future findings regarding the informal learning needs of the other stakeholder groups (i.e. managers, researchers and commercial fishers).

6. Using network analysis to appraise the importance of information sources to fisheries stakeholders

This chapter builds upon Chapters Four and Five, which identified several important drivers and constraints affecting informal learning in fisheries stakeholders, and mapped the relationships between them in recreational fishers.

This chapter seeks to complement those findings through identifying the sources of scientific information fisheries stakeholders currently use, and using network analysis, identify patterns that could be used to make communication strategies aimed at fisheries stakeholders more efficient and effective. Network analysis was employed to identify shared information sources between stakeholders, assess the relative importance of each information source to stakeholders, identify the formats stakeholders prefer their scientific information to be presented in, and assess whether the authority an information source represented affected whether stakeholders were likely to depend upon it.

This chapter has been prepared as a stand-alone manuscript for submission to *Ecology and Society*.

Note: The data used to construct the networks/matrices in this chapter came from the same set of interviews used to gather data for Chapter 4.

6.1 Introduction

The previous chapters in this study have worked towards finding ways to facilitate the effective uptake of scientific information among fisheries stakeholders. This chapter focuses on potentially improving the efficiency of those efforts through mapping out information sources that link/separate fisheries stakeholders. The intention of this chapter is to identify specific information sources or types of information sources that might allow communicators to target multiple stakeholder groups simultaneously, and also to identify those more isolated stakeholders who might be more reliant on information more removed from the original source(s) (i.e. primary literature, scientists, grey literature).

Thus far, very little formal, scientific attention has been dedicated towards identifying where fisheries stakeholders access their scientific information. Some research has been conducted into how commercial fishers share fishing related information, and also how stakeholders use information from scientific government reports in the management of Caribbean fisheries (Soomai et al., 2011; Evans and Weninger, 2014). Others have even applied network analysis techniques to understand the flow of social capital and governance networks in other fisheries (Hartley, 2010; Barnes-Mauthe et al., 2015). However, the listed research has been conducted in a formal, science-policy context, or concerns the flow of non-scientific information between stakeholders with vested interests. Few existing studies address the flow of scientific information (in all its forms) throughout stakeholder communities in formal and informal contexts. Correspondingly, little is understood about how stakeholders' use/reliance upon specific sources of scientific information might affect the flow of information among stakeholder groups. The current literature offers little guidance in terms of identifying sources of scientific information that various fisheries stakeholders are likely to share, or rely upon. The lack of knowledge about where fisheries stakeholders acquire their information is to the detriment of modern fisheries management. Understanding where stakeholders acquire their information, and how well networked they are, aids in improving, preserving or creating information connections between stakeholder groups.

At a fundamental level, a lack of understanding of which information sources fisheries stakeholders rely upon makes strategic communication decisions difficult (Treise and Weigold, 2002; Frank et al., 2009; Cvitanovic et al., 2014). An inability to identify shared information sources limits communicators' abilities to target information sources that would allow messages to diffuse through the stakeholder community most efficiently. An inability to identify and target the key information sources that specific stakeholder groups prefer or rely upon, hampers communicators' efforts to maximise the rate of their messages' uptake within specific stakeholder groups. Understanding stakeholders' information networks and how they are networked also potentially allows the identification of marginal groups relying on secondary information, or with weak ties to reputable sources. This last aspect is invaluable from a fisheries management and compliance perspective. Steps can be taken to strengthen stakeholders' ties to the original source of the information, or a more proactive approach can be taken to communicate high quality information through the information sources that targeted stakeholders rely most heavily upon. Fisheries management stands to benefit greatly from identifying not only the information sources fisheries stakeholders rely upon, but also the way they are connected to the various stakeholder groups.

The following section reviews current literature about the information sources fisheries stakeholders are likely to be using, and variables that could be used to characterise them. The review section also discusses the potential for network analysis techniques applied to mapping the information pathways between fisheries stakeholders to give novel insights useful to management agencies, and those developing communication/outreach strategies aimed at fisheries stakeholders.

6.1.1 *Importance of identifying information sources relied upon by fisheries stakeholders*

As the conceptualisation of fisheries systems has increased in complexity, the diversity of scientific disciplines and stakeholders engaged in its management have correspondingly increased (Johannes, 1981; Freeman et al., 1991; Gigliotti and Peyton, 1993; Berkes et al., 1995; Nielsen and Vedsmand, 1995; Janssen and Goldsworthy, 1996; Jentoft et al., 1998; Ewel, 2001; Kaplan and McCay, 2004; Granek et al., 2005). Management agencies are now faced with the question of how to effectively communicate information from a range of scientific disciplines (social, economic and ecological) to a diverse range of fisheries stakeholders with diverse scientific backgrounds (e.g. commercial and recreational fisheries, fisheries managers, general public, etc.) (Soomai et al., 2011). One vital step towards improving the way scientific information is communicated to fisheries stakeholders is to first establish where those stakeholders are sourcing scientific information.

Not knowing which information sources (e.g. primary literature, fishing media, direct interactions with scientists etc.) stakeholders rely upon hinders communication efforts beyond not knowing how to improve a message's exposure to the audience, and makes gauging the form and quality of the information reaching those stakeholders difficult. There is potential for certain stakeholders to be more reliant on secondary or tertiary sources of information[4], increasing the potential for sectors of the stakeholder community to be misinformed (Ditton et al., 1992; Nisbet et al., 2002; Cvitanovic et al., 2014). Those stakeholders most likely to be reliant upon 'secondary' sources of scientific information are those who are further removed from the research (i.e. those who have little or no opportunity or willingness to be involved in research or directly, physically access its results), and highly dispersed i.e. commercial and recreational fishers (Ditton et al., 1992). Additionally, in most cases, fishers' roles in fisheries management are voluntary and informal. As a result, fishers are generally more dependent on highly mediated and potentially derived communication than fisheries managers and researchers, with most accessing their scientific information in indirect and sometimes highly modified forms (Ditton et al., 1992; Li et al., 2010).

[4] For the purposes of this chapter, a secondary information source is defined as an information source that references the original study. A tertiary information source is one that references a secondary information source. For example, a journalistic article referencing the original information source could be considered a secondary information source. A social media post referencing that journalistic article would be considered a tertiary information source.

However, it would appear that a dependency on secondary sources of information might not be limited to commercial and recreational fishers. Evidence suggests that some managers might also be relying less upon peer-reviewed, primary literature than they traditionally have (Soomai et al., 2011; Cvitanovic et al., 2014). A recent publication by Cvitanovic et al. (2014) showed that very little of the available primary literature about coral reef ecosystems was cited in government policy documents, strategies, management plans or reports regarding marine park management in Australia, Belize and Kenya (Cvitanovic et al., 2014). Instead, many managers appeared to be relying upon personal experience, and secondary sources of information (e.g. reports and literature reviews citing the original studies) to make their decisions (Cvitanovic et al., 2014). The study by Soomai et al. (2011) cited multiple instances where scientific government reports were considered too technical and long to be useful for fisheries managers, policy makers and members of the fishing industry in the management of Caribbean fisheries. Additionally, this study also pointed out the fact that many stakeholders (particularly resource users) were unaware of the relevant, available scientific information, or unable to access it despite its publication in digital avenues (Soomai et al., 2011). These studies highlight how even those stakeholders who are closest to the research and have long-standing relationships with scientific institutions can be reliant upon 'secondary' information because they find the original studies/reports too difficult or time-consuming to access, digest and use. Clearly, there is a need to identify where the information informing fisheries management comes from, how it is disseminated, how it reaches the various stakeholders and, correspondingly, the most suitable pathways for improving information transfer.

This chapter deals with three of the foremost questions:

1. Where do fisheries stakeholders get scientific information, and do sources differ across stakeholders' roles (i.e. recreational fishers, commercial fishers, scientists, managers)?

2. Which types of information do fisheries stakeholders performing different roles prefer?

3. Which sources do fisheries stakeholders performing different roles primarily rely upon for their information?

6.1.1.1 Where do fisheries stakeholders get scientific information, and do sources differ across stakeholders' roles?

Before any further analysis can ensue, it is first necessary to identify those information sources likely to be used by fisheries stakeholders. Some fisheries stakeholders such as managers and researchers have long standing, highly formalised methods of communicating science (e.g. scientific journals and reports) (Clay and Goodwin, 1995; McPhee, 2008). Government reports, primary literature, grant applications, formal meetings and scientific conferences are just some of the ways that fisheries managers and researchers communicate the state of their current scientific knowledge, future research directions, and the implications of their findings (McPhee, 2008; Cvitanovic et al., 2014). Where commercial and recreational fishers are likely to access their scientific information is less clear. Having had a longer working relationship with management agencies, commercial fishers are more likely to have direct access to more formal sources of scientific information such as government reports than recreational fishers (McPhee, 2008). However, little work has been done to document where recreational fishers source their scientific fisheries information. This absence of research might in part be due to the fact that recreational fishers as a community are typically widespread and, therefore, more reliant on informal, highly mediated forms of communication (Ditton et al., 1992). The fact that recreational fishers appear to be more reliant on informal, highly mediated forms of communication should be a concern to management agencies. Being more reliant on information sources of this nature makes it more difficult to ensure that recreational fishers are getting accurate, high quality scientific information. Part of this study aims to identify any stakeholder groups that might be at risk of being more distant from the original scientific information and, therefore, in danger of miscommunication or misinformation.

6.1.1.2 Which information types do fisheries stakeholders performing different roles prefer?

This study also explores whether certain characteristics of existing information sources might make fisheries stakeholders more or less dependent on them. Certain types of information might be less appealing than others due to a number of factors, including cognitive accessibility and time pressures (Bauer, 1992; Berkenkotter and Huckin, 1995; Frank et al., 2009; Cvitanovic et al., 2014). For example, a recent study showed that managers and conservation planners relied less upon scientific literature due to time constraints and the technical nature of the literature, preferring instead personal correspondence with scientists (Cvitanovic et al., 2014). Chapter Four further confirmed this issue, documenting instances where, due to time constraints and cost, fisheries managers relied upon personal interactions with the primary investigators doing research of interest instead of purchasing and reading the resultant publications. This chapter seeks to illustrate any effects of information type on stakeholders' reliance upon/use of existing information sources.

6.1.1.3 Which authorities do fisheries stakeholders performing different roles primarily rely upon for their information?

Another characteristic that might affect fisheries stakeholders' tendencies to rely upon/use certain forms of information might be where the information comes from. Chapter Four of this thesis identified the fact that fisheries managers and researchers are more inclined to trust information that comes from a source as close to the scientific origin as possible (i.e. peer-reviewed, scientific journal articles, or the investigating scientist). Existing literature also suggests that the source of a piece of information also affects the likelihood of members of public to uptake scientific information (Hornig, 1990; Durant et al., 1992; Nelkin and Lindee, 1995; Critchley, 2008). Aside from gaining an understanding of which presentations of information might be more appealing to fisheries stakeholders, categorising information by its sources also gives insights into how distant that information is from the original, scientific origin.

6.1.1.4 The value of applying network analysis

This study aims to improve the effectiveness and efficiency of how scientific information is communicated between fisheries managers, researchers and commercial and recreational fishers. The aim is achieved through applying network analysis to a series of networks illustrating fisheries stakeholders' usage of existing information sources. Social network analysis has been used in the past to study information flow between stakeholder groups and marine governance organisations (Cohen et al., 2012; Weiss et al., 2012). In this chapter, network analysis will be used to quantify the relative importance of specific information sources to fisheries stakeholders/groups of fisheries stakeholders.

One of many ways to construct networks is to use a spring-embedding algorithm. In networks constructed using spring-embedding, variables with the most connections in common are placed closer together, whereas those with the least connections in common with other variables are placed further away (Borgatti, 2009; Cinner and Bodin, 2010). Correspondingly, the most well connected variables will tend to be in the centre of the network, while those with fewer or weaker connections will be on the periphery (Borgatti, 2009; Cinner and Bodin, 2010). Spring embedding therefore illustrates the relative importance of a variable to a network, and how similar it is to other variables (Borgatti, 2009; Cinner and Bodin, 2010). In the context of this chapter, the positioning of information sources relative to the individual stakeholders, and stakeholder groups would reflect the number of information sources they have in common. Likewise, networks constructed based on the formats of the information sources, and the authorities they represent, are used to gauge whether certain stakeholders/stakeholder groups are typically reliant on information presented in certain formats, or from particular authorities. Other potentially valuable insights that could come from applying spring-embedding to the construction of networks illustrating fisheries stakeholders' historical use of information sources include:

1. The relative importance of specific information sources to fisheries stakeholders;

2. The identification of information sources with the capacity to reach multiple stakeholder groups and information sources that could be used to reach stakeholders who do not share information sources with many other stakeholders;

3. The quality of the information that stakeholders across the network are accessing and the identification of stakeholders who are more reliant on less reputable sources of scientific information.

6.1.1.5 Using network metrics to calculate the relative importance of specific information sources and assess their reach across the stakeholder community and to more remote stakeholder groups

Typically, networks can be analysed using a number of centrality measures. One centrality measure that has potential as a measure for an information source's impact on a range of stakeholders is the Eigenvector. The Eigenvector is often used to gauge the impact that a specific node has on the network as a whole (i.e. the higher a node's Eigenvector, the more influence it has over all the other nodes across the network) (Borgatti and Everett, 1997; Hanneman and Riddle, 2005). Calculating the Eigenvector of information sources is likely to help identify those information sources that are most heavily relied upon by the widest range of stakeholders. An information source with a high Eigenvector will be better connected to stakeholders from across the entire network than one with a low Eigenvector, and therefore be more likely to reach stakeholders from across the entire network (Borgatti and Everett, 1997; Hanneman and Riddle, 2005). Likewise, if a particular information type has a high Eigenvector, then that particular information type is most likely to be most familiar and heavily relied upon by more stakeholders across the network, and also the most familiar to the more well-informed stakeholder groups. Identifying the individual information sources and formats with the highest Eigenvectors would therefore allow those designing communication strategies aimed at fisheries stakeholders to make the most efficient choices regarding potential publishing avenues, and the most appropriate formats.

The application of the Eigenvector to the source of pieces of scientific information has practical applications for communication professionals and management agencies alike. For communication professionals, benefits to applying the Eigenvector include the ability to gauge where they should focus their efforts. For example, should information sources representing the public media have a significantly higher Eigenvector than information sources representing government agencies, or academia, communication professionals might need to focus their efforts on publishing in the public media, rather than producing more government publications. Correspondingly, management agencies will also be able to assess the effective reach of their communication efforts. If government resources have a low Eigenvector, agencies might like to question why, while also refocusing their efforts so that their messaging reaches the wider stakeholder community. Management agencies can also use the Eigenvector as an indicator of whether they need to build stronger relationships with other information sources. For example, if the public media had a higher Eigenvector than government publications (i.e. public media reached a wider range of stakeholders than government publications), management agencies might wish to cultivate a closer relationship with the public media to mitigate any potential miscommunication/misinformation that might otherwise reach the wider stakeholder community and cause conflict (Nisbet et al., 2002).

6.1.1.6 Evaluating the quality of the information stakeholders are accessing and identifying stakeholders more reliant on less reputable sources of scientific information

Applying network analysis to stakeholders' use of information sources also allows the testing of existing assumptions about fisheries stakeholders, and the information sources they rely upon. Historically, it has been assumed that fisheries scientists and managers rely most heavily upon primary literature for their scientific information, while commercial and recreational fishers, like other members of the wider public, are more likely to rely upon more heavily mediated information sources (LaFollette, 1990; Nelkin, 1990; Ditton et al., 1992; Endter-Wada et al., 1998; Jacobson and McDuff, 1998). However, recent studies, including Chapter 4, have indicated that scientists and managers may be relying upon other information sources owing to constraints such as a lack of time and/or money (Boud and Middleton, 2003; Cvitanovic et al., 2014). By using spring-embedding and measures such as the Eigenvector to investigate stakeholders' relationships with information sources/categories of information sources, this study seeks to test the relative importance of those information sources to stakeholders and, therefore, the validity of those assumptions.

6.1.2 Aims and research questions

The major aim of this chapter is to explore the use of network analysis in gauging the efficiency of current efforts to communicate scientific information to fisheries stakeholders, and identifying areas that could require improvement.

This aim will be achieved through answering the following research questions:

1. Which information sources are most central to fisheries stakeholders' information networks?

2. How does a stakeholder’s primary role in the fisheries management system affect his/her reliance on the various information sources?

3. Which formats do fisheries stakeholders rely more heavily upon?

4. Which authorities do the information sources fisheries stakeholders depend upon represent?

5. How can those stakeholders who are more remote in the information network be reached more effectively?

6.2 Methods

The data used to construct the networks presented in this chapter came from the semi-structured stakeholder interviews conducted in Chapter Four (i.e. the study location and sample are identical).

6.2.1 Study location

This study was performed in the Great Barrier Reef region in Northern Queensland, Australia. The region stretches from Cooktown in the north, to Rockhampton in the south. The stakeholders who were interviewed were mostly from the Townsville area, though their activities and jurisdictions spanned the marine park. Some fisheries managers and researchers were located in Brisbane, though their professional interests and responsibilities had direct relevance to the Great Barrier Reef region.

6.2.2 Sample

Fisheries managers, scientists and commercial and recreational fishers from the Great Barrier Reef region were interviewed for this study [Table 6.1]. The managers and researchers were from several agencies with jurisdictional concerns in the Great Barrier Reef Marine Park. The commercial fishers were from a range of fisheries [Table 6.1]. The recreational fishers were not subdivided by fishing type (e.g. pelagic, inshore etc.) as they often practise numerous forms of fishing throughout the year and are not restricted to any one kind of activity.

Table 6.1 Breakdown of study population with stakeholders grouped according to their primary roles in the fisheries management system. GBRMPA: Great Barrier Reef Marine Park; DAFF: Department of Agriculture, Fisheries and Forestry; CSIRO: Commonwealth Scientific and Industrial Research Organisation.

Stakeholders grouped according to their primary roles	Agencies/sectors represented	Number
Managers	GBRMPA, DAFF	8
Scientists	DAFF, CSIRO	9
Commercial fishers	Northern prawn fishery, Spanish mackerel fishery, coral reef fin fish fishery,	5
Recreational fishers	NA	7

6.2.3 Survey data

Most of the fisheries stakeholders interviewed lived in the area adjacent to the Great Barrier Reef Marine Park, and were interviewed on an individual basis, either in person or using the telephone. Several managers and scientists did not reside in the area, although their study sites or jurisdictions did include the GBR region. These managers and scientists were also interviewed in person where possible, and using the telephone when that was the only option. When it was possible and appropriate to conduct interviews in person, interviews were arranged for a time most convenient for the respondents, and at a place of their choosing.

Stakeholders were asked to list as many information sources as possible that they had used in the past to acquire scientific fisheries information. Stakeholders were deliberately asked for information sources they had previously used to prevent them from volunteering information sources that they thought might be useful, but had never used. If stakeholders had mentioned information sources earlier on in the interview, but did not list them when asked, they were probed for the reasoning behind the omission. If the reasoning was a memory lapse, then these information sources were also included in that individual's list of preferred information sources. Only information sources that were used to source information related to actual fisheries science were included in the lists (i.e. information sources used to acquire information about fishing reports, fishing techniques etc. were not considered relevant).

Each interview was voice recorded and transcribed before the results were input into bimodal matrices with stakeholders on the y-axis, and information sources on the x-axis. Stakeholders were grouped according to their primary roles in the fisheries management system (i.e. an individual grouped as a manager primarily acts as a manager in the fisheries management system, but not necessarily to the exclusion of other roles).

Approval for this research was granted by the James Cook University Human Research Ethics Committee (Ethics application number: H4079), and all interviewees were asked to sign an informed consent form before the commencement of the research activity.

6.2.4 Identifying the information sources depended upon most by stakeholders according to their primary roles in fisheries management

Instances where stakeholders had mentioned using an information source in the past were recorded. To prevent the over-representation of certain individuals/stakeholders performing particular roles, references to information sources were recorded on a presence/absence basis (i.e. referrals to information sources were only recorded once for each individual regardless of how often they mentioned it later in the interview). The number of references to each information source was recorded for each group of stakeholders with common primary roles, as was the total number of references to information sources in general. The tabulated results were used to inform the construction of the networks, give an overall impression of which information sources stakeholders sharing specific roles relied upon most, and to illustrate how well connected stakeholders sharing certain roles are on average to the various information sources.

Single factor ANOVA was used to compare information sources against each other in terms of their popularity among fisheries stakeholders, as well as according to the authorities each information source represented, and the information type.

6.2.5 Network analysis

A bootstrap approach (n=5000) was used to check for non-random patterns in each network. The bootstrap approach has been used in previous studies to assess the legitimacy of criteria used to group networks based on commercial fishers' information sharing patterns (Ramirez-Sanchez, 2011). In the context of this study, the bootstrap approach has been used to test the following:

- Whether grouping fisheries stakeholders according to their primary role in the fisheries system affects their reliance upon existing information sources in a non-random fashion
- Whether information type, or its source, affects fisheries stakeholders' usage of those information sources in a non-random fashion.

Using the UCINET6 package, the nodes (i.e. the row/column labels) were randomly permuted within each bimodal matrix and networks were created using the same nodes as the original matrix i.e. the procedure maintains the links between the two sets of nodes while randomising nodes within each set (Borgatti et al., 2002). Density was then calculated for each of the 5000 random networks (i.e. the expected density) and checked against the calculated density from each observed network using the same software package (Borgatti et al., 2002). Since this is an exploratory study, and because the sample size was small, a significance level of $P<0.10$ was used. Non-random networks were drawn using spring-embedding, and the effects of information sources' formats, and the authorities those sources represented were tested and analysed.

The networks presented in this study are bimodal. Bimodal networks are constructed from matrices where the column labels do not match the row labels (i.e. the network looks at how two non-identical lists of variables affect one another). Therefore, calculating density (D) in the usual (i.e. unimodal) way is inappropriate. Calculating the density of bi-modal networks using the traditional formula where the number of connections (C) is divided by a denominator of N^2 or $N(N-1)$) is does not work because there are no possible relationships within row and column sets (Borgatti and Everett, 1997). It is suggested that for bimodal networks where the size of row and column sets are N_i and N_o, that the number of connections (C) should be divided by the adjusted denominator of N_iN_o for an undirected graph (Borgatti and Everett, 1997). Because the stakeholders interviewed in this study were only asked about the source(s) of their scientific fisheries information, and no information was recorded regarding whether the information sources interacted with each other, it was necessary to apply the denominator suitable for undirected graphs (Borgatti and Everett, 1997) i.e.

$$D = \frac{C}{N_i N_o}$$

The UCINET6 software package calculates densities for bimodal networks using the above formula, therefore, that was used to calculate the densities for each network (Borgatti et al., 2002).

6.2.5.1 Calculating the effect of stakeholders' primary roles

Matrices were constructed grouping stakeholders' primary roles (i.e. according to whether they primarily identified themselves as fisheries managers, scientists, commercial and recreational fishers). The resultant matrices were tested to gauge whether stakeholders' primary roles are a good indicator of which particular information sources they are likely to rely upon, as well as whether the information's source, or the information type, have any significant effect.

6.2.5.2 *Calculating the effect of information type and its source*

To gauge whether the source of a piece of information, or its type (i.e. the way it was presented), affected stakeholders' networks, matrices were constructed including all participants, with the information sources categorised by 'source' and 'information type' [Table 6.2].

Table 6.2 Information sources elicited during semi-structured interviews sorted by their sources, and by information type. *Note: While meetings regarding fisheries issues are often instigated by government, meetings were not categorised as representing government authorities to the exclusion of others because fisheries stakeholder meetings are also often held by academic institutions, NGOs and private consultancies. Also, 'contact with organisations' describes instances where stakeholders have chosen to directly contact organisations of interest. Instances where stakeholders had direct interactions with a specific stakeholder group/groups were categorised as such.*

Individual information sources	Source	Information type
Universities	Academia	Contact with organisations
Primary literature	Academia	Scientific literature
Textbooks	Academia	Academia
Fishing magazines	Fishing media	Print media
Fishing shows (TV)	Fishing media	Television
Govt. agencies	Government	Contact with organisations
Govt. databases	Government	Online database
Govt. publications	Government	Print media
Govt. websites	Government	Website
Govt. research reports	Government	Scientific literature
Industry magazines	Industry media	Print media
NGO publications	Non-government organisations	Print media
NGO websites	Non-government organisations	Website
NGOs	Non-government organisations	Contact with organisations
NGO databases	Non-government organisations	Online database
News (TV)	Public media	Television
Newspapers	Public media	Print media

Radio	Public media	Public media
Managers	Managers	Managers
Researchers	Researchers	Researchers
Commercial fishers	Commercial fishers	Commercial fishers
Recreational fishers	Recreational fishers	Recreational fishers
Internet (other)	Internet (other)	Internet (other)
Meetings	Meetings	Contact with organisations
Other	Other	Other

6.2.5.3 The use of spring-embedding and Eigenvector to identify useful patterns

Constructing 'community' networks based on stakeholders' and information sources' attributes using a spring-embedding algorithm allows several research questions to be addressed. Spring embedding places those nodes with the greatest similarity closest together (Borgatti, 2009; Cinner and Bodin, 2010). The most well connected, and most closely related, nodes will therefore be closest to the centre of the network (Borgatti, 2009; Cinner and Bodin, 2010). Therefore, spring-embedding was applied to the networks generated in this study to give a visual representation of the information sources stakeholders rely upon most heavily, and importantly, which information sources stakeholders are likely to share.

The sizes of the nodes in the networks presented in this chapter were calculated according to their Eigenvector. The higher an information source's Eigenvector, the larger the node. A high Eigenvector would indicate that an information source has great influence over stakeholders from across the entire network (Borgatti and Everett, 1997; Hanneman and Riddle, 2005). The Eigenvectors of each node in the networks presented in this chapter were calculated using Netdraw, part of the UCINET6 package (Borgatti et al., 2002).

6.3 Results

6.3.1 Frequency of stakeholders' references to information sources

This section shows that managers, scientists, and commercial and recreational fishers are using specific information sources at different rates. Managers rely upon more information sources than the other stakeholder groups (approximately seven sources per person) [Table 6.3]. Recreational fishers, commercial fishers and scientists relied on a similar number of information sources (approximately five, five and six sources per person respectively). Scientists were relied upon most heavily as information sources by commercial fishers, recreational fishers and other scientists [Table 6.3]. Managers relied most heavily on government agencies and primary literature for their information [Table 6.3]. The fisheries stakeholders sampled for this study relied heavily upon communications with scientists for their fisheries science [Table 6.3].

Table 6.3 Number of individuals from each stakeholder group who used each information source. Cells containing the most heavily used information source for each stakeholder group have been shaded grey.

Information source	Commercial fishers (N=5)	Recreational fishers (N=7)	Scientists (N=9)	Managers (N=8)	Average no. references to information source per stakeholder group
Commercial fishers	1	0	1	4	1.5
Fishing magazines	0	3	0	1	1
Fishing show TV	0	0	0	0	0
Govt. agencies	2	2	1	8	3.25
Govt. databases	0	0	1	2	0.75
Govt. publications	2	1	4	4	2.75
Govt. websites	3	2	1	0	1.5
Govt. research reports	2	1	4	6	3.25
Industry magazines	1	0	0	0	0.25
Internet search	2	4	5	3	3.5
Managers	1	2	1	2	1.5
Meetings	1	0	1	2	1
Newspapers	0	2	1	2	1.25

News (TV)	1	2	0	1	1
Non-govt. databases	0	0	0	0	0
Non-govt. Orgs	0	0	3	2	1.25
Non-govt. publications	0	1	1	0	0.5
Non-govt. websites	0	3	1	1	1.25
Other	1	0	2	0	0.75
Primary literature	1	2	7	8	4.5
Radio	1	1	0	0	0.5
Recreational fishers	0	4	3	3	2.5
Scientists	4	5	9	7	6.25
Textbook	1	1	1	1	1
Universities	0	1	4	2	1.75
Total	**24**	**37**	**51**	**59**	
Average	**4.8**	**5.4**	**5.7**	**7.4**	

An ANOVA comparing the rates at which information sources were used (i.e. as displayed in Table 6.2), revealed that the elicited information sources were being used at significantly different rates by fisheries stakeholders [Table 6.3]. Further analyses confirmed that the authorities that information sources represent, and the formats they are presented in, also significantly affect whether stakeholders have used/relied upon them in the past [

Table **6.4**]. These results suggest that there is a significant, though unknown, effect that warrants further exploration. The following sections present the results from these explorations.

Table 6.4 Single factor ANOVA comparing information sources by their popularity among stakeholders (significant at P<0.10).

Comparisons	SS	MS	F	df	P
Between information sources (n=25)	214.3	8.9	3.8	24	0.001
Between sources (n=12)	75.5	6.9	18.4	11	0.001
Between information types (n=14)	50.2	3.9	13.1	13	0.001

6.3.2 The effect of stakeholders' primary roles on their reliance on information sources using network analysis

Within each stakeholder group, information type did not have a significant effect on whether an individual was likely to depend upon that information source [Table 6.5]. The source of the information also had no significant effect on whether an individual was likely to depend upon that information source [Table 6.5]. Therefore, stakeholders' primary roles in fisheries management alone were poor indicators of whether they were more reliant on information sources of a certain type, or from a specific source.

Table 6.5 Results of tests performed using the bootstrap approach (N=5000) for matrices where individuals are categorised by stakeholder group (significant at P<0.10). Analysis has been performed for networks relating stakeholder group to uncategorised information sources, information sources sorted by their 'type', and information sources sorted by their sources. *Note: The standard error presented here is one calculated using the bootstrap method (Borgatti et al., 2002).*

Networks	Expected density	Estimated standard error	z-score	P value
Information sources not sorted				
Commercial fishers (N=5)	0.192	0.100	0.418	0.34

Managers (N=8)	0.295	0.094	0.000	0.50
Rec fishers (N=7)	0.211	0.069	0.006	0.50
Scientists (N= 9)	0.227	0.081	-0.004	0.50
Information sources sorted by format				
Commercial fishers (N=5)	0.329	0.157	0.088	0.46
Managers (N=8)	0.201	0.181	0.688	0.25
Rec fishers (N=7)	0.179	0.188	0.273	0.39
Scientists (N= 9)	0.171	0.130	0.491	0.31
Information sources sorted by their source				
Commercial fishers (N=5)	0.150	0.325	0.769	0.22
Managers (N=8)	0.417	0.251	0.787	0.22
Rec fishers (N=7)	0.357	0.152	0.550	0.29
Scientists (N= 9)	0.389	0.148	0.564	0.29

6.3.3 The effect of information type and source for all stakeholders combined

An information source's 'type' and specific identity had no significant effect on networks illustrating which information sources the combined stakeholder population (i.e. recreational fishers, commercial fishers, managers and researchers) relied upon most [

Table **6.6**]. The one variable that significantly affected networks illustrating how likely a stakeholder was to rely upon an information source was its source ($P<0.10$) [Table 6.6].

Table 6.6 Results of tests performed using the bootstrap approach (N=5000) for matrices including all stakeholders and their relationships with information sources (not sorted), information sources sorted by their 'type', and information sources sorted by sources. *Note: The standard error presented here is one calculated using the bootstrap method (Borgatti et al., 2002).*

Networks	Expected density	Estimated standard error	z-score	P value
All information sources, all stakeholders (N=29)	0.236	0.040	-0.004	0.49
Information sources by 'type', all stakeholders (N=29)	0.352	0.062	1.120	0.13
Information sources by sources, all stakeholders (N=29)	0.374	0.078	1.502	0.07

6.3.4 Using spring embedding to gain insights into information sources stakeholders rely upon most heavily

One network illustrating that the authority an information source represents affects the likelihood of individual stakeholders relying upon it was significant at P<0.10 [Figure 6.1]. This network suggests that information from the government, academia and scientists are depended upon most by fisheries stakeholders. These three authorities have high Eigenvectors, indicating that they have the most, and closest, linkages to the stakeholders as a whole, as opposed to having tight relationships with a localised cluster of stakeholders [Figure 6.1] (Hanneman and Riddle, 2005). Commercial fishers, managers, wider internet searches, the fishing industry, and public media appear to be used by relatively fewer fisheries stakeholders, and often by those who were less well connected than others to the elicited information sources [Figure 6.1].

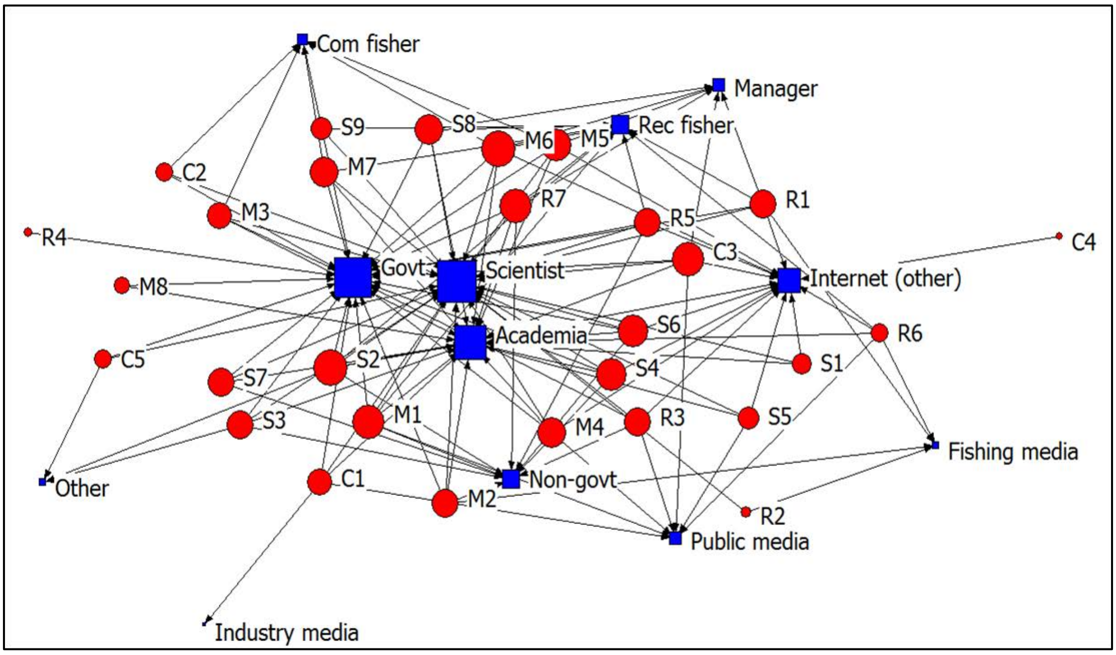

Figure 6.1 A network illustrating stakeholders and the information sources they rely upon sorted by their corresponding sources (N=29). Individual interviewees are represented by circular nodes denoted S1, S2 etc. (R= recreational fisher; C= commercial fisher; M= manager; S=scientist). Square nodes represent information sources. The nodes in this network increase in size according to their Eigenvector. In this network, government, academia and scientists are being used as information sources by more individuals than any other, and have the greatest influence over the network as a whole (P=0.07).

6.4 Discussion

The results of this study revealed that certain information sources are relied upon more than others. The way information is presented (i.e. information type) and the source of that information can significantly affect how heavily it is relied upon by fisheries stakeholders. Scientists and commercial and recreational fishers appeared to rely more heavily upon direct interactions with scientists for their scientific information, while managers relied more heavily on government departments and primary literature. Scientists appeared to be the most relied upon information source, with primary literature being the second most heavily relied upon (mostly due to its heavy usage by other scientists and managers). Of all the resources listed in this study, scientists also appeared to have the greatest reach across all the stakeholder groups as a source of scientific information. The finding that commercial and recreational fishers depend heavily upon scientists for their scientific information is perhaps unexpected (Ditton et al., 1992). The results suggest that while fishers might usually depend more heavily on mediated forms of communication between one another, they might be accessing scientific information somewhat differently. However, this finding might also be attributed to survey bias. High centrality/highly avid fishers are more likely to volunteer for surveys and are, therefore, more likely to come into contact with scientists and their studies (McInnes, 2006). Therefore, while these results suggest a dependency upon scientists and primary literature, it is important to remember that this was an exploratory study with a correspondingly small sample size. A larger, more representative sample would be necessary before any concrete conclusions could be made based on these networks. In particular, because there are many more commercial and recreational fishers than there are fisheries researchers and managers, a much larger sample of commercial and recreational fishers is likely to be required to generate a truer network of the fisheries stakeholder community. While a network generated using this approach might appear to be potentially biased towards the needs of commercial and recreational fishers due to their numerical advantage, the following paragraphs discuss why this might not be the case.

The results of this study suggest that grouping individual fisheries stakeholders according to their roles (i.e. as managers, scientists, or commercial or recreational fishers) might be inappropriate for assessing their information/communication needs. All the networks constructed for this study where stakeholders were grouped according to their primary roles were not significantly different than random. The only non-random network illustrated that the authority which an information source represented significantly affected whether fisheries stakeholders (as individuals) were likely to use it. The fact that the only significant network generated was one based on individuals, and not stakeholders' roles, reinforces the fact that it is possibly erroneous to arbitrarily group stakeholders according to their role(s) when designing communication strategies. This finding is particularly worrying as papers discussing how science should be communicated to fisheries stakeholders have traditionally focussed on the differences between stakeholders' roles, and the need to overcome them (Jacobson and McDuff, 1998; Kaplan and McCay, 2004; Degnbol, 2005). This study indicates that while, in some cases, a stakeholder's role might have some bearing on the best way to communicate scientific information to them, there are other parameters that might be just as important, if not more so.

There is much evidence to suggest that the perceived relevance of a message or information source also influences whether scientists and managers are likely to use an information source. A recent study indicated that marine conservation managers in many countries almost exclusively cited literature that was directly relevant to their geographical area in their grey literature, and preferred not to extrapolate findings from studies done overseas (Cvitanovic et al., 2014). Similarly, the perceived relevance of scientific information has also been shown to effect the way that information informs the making of policies on the science-policy interface (McNie, 2007; Sarkki et al., 2013, 2015). Possibly, communication strategies aimed at fisheries stakeholders focusing on how the fundamental variables (i.e. the information's clarity and familiarity, its perceived usefulness/relevance, and emotions associated with its origins or implications) affect the target audience will prove more constructive, than those focused on stakeholders' arbitrary roles (Chapters 4 & 5).

The results of this study are congruent with existing mass communication literature, which indicates that the most effective communication is targeted towards a specific behaviour and motivation (Ward and Wilkinson, 2006; Brochu and Merriman, 2008; Ham, 2013). The results of this study suggest that the ideal format/outlet for the information to be communicated is also likely to be very situational. Chapter 4 identified many instances where stakeholders' informal learning was influenced by the same suite of variables, but for very different reasons. For example, the conative dimension (i.e. regular usefulness) was found to influence informal learning in all the groups of fisheries stakeholders (i.e. managers, scientists, commercial and recreational fishers). However, the way the conative dimension/regular usefulness of this information was expressed was very different between the stakeholder groups, and individual stakeholders (Chapter 4). Multiple managers prioritised the relevance of the new information to their work, while commercial and recreational fishers prioritised the relevance of the information to their fishing activity (Chapter 4). In this sense, it is still possible that a stakeholder's role might affect the information sources they seek/rely upon by affecting the way they contextualise variables such as clarity, regular usefulness, good and bad emotion, and also what might constrain their interest in a piece of information (Chapter 5). Further research into the communication of scientific information to fisheries stakeholders therefore needs to explore the way that a stakeholder's role might affect these variables and the relationships between them, rather than assume that there must be a clearly defined difference between the stakeholder groups.

6.5 Future Research

This chapter established that while the information sources elicited from the interviewees were used in significantly different ways, stakeholders' roles were not necessarily the reason for those differences. This section includes suggestions for future research directions based on those findings.

The lines of questioning used to gather information about stakeholders' information sources should be as specific as possible. In this chapter, stakeholders were asked where they had previously sourced fisheries related scientific information. The intention at the time was to capture as many information sources as possible. However, the information gathered resulted in networks that could not capture stakeholders' nuanced and deliberate information sourcing habits (e.g. how relevant the information they were seeking was to their activity of interest). For example, this study could not neatly distinguish between instances where managers and scientists approached fishers, or analysed media stories for scientific data, or when they were looking for information from more orthodox sources (e.g. primary literature and government reports etc.). Knowing these things would give context to stakeholders' interactions with information sources. This context, and the information's relevance to stakeholders' interests and professional activities, is likely to be a far better predictor of where stakeholders seek/access their information, than their roles.

It is also recommended that future studies attempting to gauge the effect of stakeholders' roles on the information sources they use/rely upon use more specific and explicit research questions. Owing to the importance of context and relevance to an individual's uptake of scientific information, it is recommended that the questions be centred upon this area (Shrigley et al., 1988; Wynne, 1993; Alsop, 1999; Fensham and Harlen, 1999; Cvitanovic et al., 2014). For example, questions should be aimed at identifying points of relevance to the stakeholders (e.g. how relevant is the information to their daily conduct/work/preferred recreational activity?), and how invested they are in the topic, or accessing that information.

6.6 Conclusions

Fisheries stakeholders seem to rely more heavily on direct contact with fisheries scientists for fisheries relevant information than other sources, with managers relying equally as heavily upon information from government agencies. Managers and researchers also rely heavily upon primary literature.

Some information sources are relied upon significantly more than others. Fisheries stakeholders also rely upon some formats of information significantly more others. The authority which an information source represents also has a significant effect on whether stakeholders are likely to rely upon it.

A stakeholder's primary role in fisheries management is a poor indicator of what information sources they are likely to rely upon. Instead, it is more likely that their reliance upon specific information sources is highly contextual and driven by a host of other variables including those identified in previous communication literature, and also Chapters Four and Five.

The findings of this final chapter complement those of Chapters Three, Four and Five. Chapters Three and Four identified variables influencing the informal learning of scientific information in fisheries stakeholders. Chapter 5 developed and demonstrated a methodology that could be used to model the complex interactions between the variables influencing informal learning in fisheries stakeholders. The findings of this chapter, yield several insights and recommendations for the design of future investigations aimed at finding information sources shared by multiple stakeholder groups, and identifying those most important for specific stakeholder groups.

The following, and final, chapter of this thesis is the discussion chapter. The discussion will put the findings of this chapter, and all the other chapters, into the context of the major aims of this thesis, and of the existing literature.

7. Discussion

7.1 Overview

Changes to the way fisheries are managed have made the effective communication of scientific information between and within stakeholder groups a higher priority. However, to date, most communication efforts have been based on trial and error, not on the application of theory or existing communication frameworks. This thesis originally aimed to create a generalised model of fisheries stakeholders' informal learning of scientific information with concrete, applied outcomes for those seeking to design better communication programs for this audience. As the research progressed, it became evident that a single, generalised model describing informal learning among all fisheries stakeholders would be inappropriate. Consequently, each of the chapters contained in this thesis resulted in a number of applied outcomes and theoretical insights deepening the understanding of how the communication of scientific information to fisheries stakeholders should be approached.

The major aim of this thesis was to develop ways to optimise fisheries stakeholders' uptake of scientific information in a fisheries management context (Chapters 2 & 3). This aim has been achieved, and this thesis represents the first formal investigation into the utility of informal learning and the components of Alsop's Informal Conceptual Change Model (ICCM) in a fisheries context (Chapter 3). New methodologies and approaches were developed and applied, generating results that allow insights into how the communication of scientific information among fisheries stakeholders can be strategically approached. The results from the research conducted in this thesis have major implications for communicators and researchers alike. This thesis has resulted in a number of applied and theoretical outcomes, some of which call into question existing preconceptions about fisheries stakeholders' communication/information needs.

The following is an overview of how the objectives of this thesis, contributing to the overall aim, have been achieved:

1. *Establish the need for further research into the communication of scientific information to and between fisheries stakeholders in a fisheries management context.*

The need for ways to strategically optimise the communication of scientific fisheries information to a broad range of fisheries stakeholders was highlighted. This need has largely been driven by the increasing adoption of ecosystem-based fisheries management (EBFM), and the active-adaptive management approach. The need for fisheries management agencies to deal with growing, increasingly multidisciplinary information loads and engage more tightly with a diverse range of fisheries stakeholders are the major reasons why research informing the construction of more efficient and effective communication strategies is becoming increasingly necessary (Chapter 2).

Existing research relevant to the design of more effective communication strategies aimed at fisheries stakeholders was sought. However, despite the review of psychology, formal and informal education, public understanding of science, media studies and human dimensions of fisheries and wildlife literature, very little was found that specifically dealt with the uptake of scientific information by fisheries stakeholders. Despite a real, applied need for research into ways to strategically address the issue of communicating scientific information to varied fisheries stakeholders, little existing research could address that need (Chapter 3).

2. *Identify variables important for fisheries stakeholders' uptake of scientific fisheries information.*

Several variables affecting fisheries stakeholders' informal learning of scientific information were identified and validated (Chapters 3 & 4). These variables were the cognitive, conative and affective dimensions (i.e. clarity of the information, its perceived regular usefulness, and emotional associations), and investments of time and money. Moreover, it was discovered that that, in some instances, the relationships between certain variables can be closely tied, and multiple variables can act in concert (Chapters 3, 4 & 5). These findings had important implications for the approach taken to address the third objective.

3. *Develop a way to model the complex relationships between variables controlling/constraining fisheries stakeholders' uptake of scientific information in a way that could be informative for communicators.*

Achieving this objective required the development and testing of a new methodology. The modelling technique employed needed to express the complex (and at times contradictory) nature of relationships between numerous variables and be flexible enough to incorporate any new, unexpected variables, should they be volunteered. With these needs in mind, a new methodology based on the fuzzy cognitive mapping (FCM) approach was developed, and piloted on recreational fishers. Network analysis techniques were also employed to add rigour to the analysis of the FCM representations of mental models elicited from recreational fishers, and the relationships between the component variables of those mental models. The new methodology and analysis techniques proved successful, resulting in several findings with a high level of agreement with existing mass communication literature (Chapter 5). Moreover, the FCM representations of fishers' mental models presented are easy to interpret, and present immediately useful information for those seeking to design new communication strategies.

4. *Map stakeholders' usage of existing information sources to identify information pathways that could make future communication efforts more efficient.*

This final objective was achieved by applying network analysis techniques to semi-structured interview data to create bimodal networks illustrating the relationships between individual stakeholders, and existing information sources elicited during the interviews (Chapters 4 & 6). The findings of Chapter Six reveal a number of information sources that were relied upon heavily by the full range of fisheries stakeholders (i.e. direct contact with scientists, government published resources and primary literature). The results also suggest that stakeholders' roles as managers, scientists or commercial/recreational fishers are poor indicators of the range of information sources they are likely to depend upon.

The following sections discuss the theoretical implications and applied outcomes of this thesis in more detail.

7.2 Contributions to the understanding of fisheries stakeholders' informal learning of scientific information

A number of key findings with implications for the interpretation and discussion of existing literature have arisen from this thesis. This section will detail the theoretical contributions from each data chapter in sequence. The theoretical contributions from each chapter are first discussed relative to their research questions, with additional insights discussed afterwards. Only those research questions that generated results with theoretical implications from Chapters Four, Five and Six are presented here. Those research questions from the aforementioned chapters aimed at generating more applied outcomes are discussed in detail in the next section. Therefore, discussions in this section begin with Chapter Four.

Chapter Four represents the first study of its kind. This study was specifically designed to identify variables important for the uptake of scientific fisheries information in a variety of fisheries stakeholders. By answering the following research questions, this chapter confirmed the applicability of informal learning theory, and identified two variables that had the potential to constrain fisheries stakeholders' informal learning of scientific fisheries information (i.e. investments of money and time):

1. How applicable is the concept of informal learning to understanding how fisheries stakeholders take up and use scientific information?

2. How applicable are the cognitive, conative and affective dimensions of informal learning to fisheries stakeholders' uptake of scientific fisheries information?

3. Are there any variables influencing the informal learning of scientific information by fisheries stakeholders that are yet to be identified in the literature?

4. What variables are likely to constrain informal learning of scientific information by fisheries stakeholders?

The applicability of informal learning theory was confirmed by testing the applicability of variables from Alsop's ICCM model (i.e. the cognitive, conative and affective dimensions) to the informal learning of scientific information among fisheries stakeholders. The applicability of informal learning theory, Alsop's ICCM model and its component variables/concepts to the uptake of scientific information is well supported by the literature (Shrigley et al., 1988; Ostrom, 1990; Alsop, 1999; Fensham and Harlen, 1999; Isen, 2001; Osborne et al., 2003; Degnbol, 2005; Cvitanovic et al., 2014). Therefore, the discovery that the component variables of Alsop's ICCM and informal learning theory were applicable to fisheries stakeholders' uptake of scientific fisheries information is unsurprising. Additionally, two constraints to fisheries stakeholders' informal learning of scientific information were uncovered in Chapter Four.

In much of the existing informal learning and public understanding of science literature, constraints on the informal learning of scientific information are discussed relative to the cognitive, conative and affective dimensions, or variations thereof (Posner et al., 1982; Shrigley et al., 1988; Ostrom, 1990; Weeks and Packard, 1997; Alsop, 1999; Fensham and Harlen, 1999; Hisschemöller and Midden, 1999; Isen, 2001; Osborne et al., 2003; Degnbol, 2005; Sarkki et al., 2013; Sarkki et al., 2015). For example, individuals' informal learning of a piece of information is likely to be constrained if the information fails to adhere to their perceptions of reality (i.e. the information causes cognitive dissonance) (Shrigley et al., 1988; Weeks and Packard, 1997; Alsop, 1999; Degnbol, 2005). Likewise, individuals' informal learning might also be constrained if the new information fails to appear useful on a regular basis (i.e. fails to appeal to the conative dimension), or if it elicits a negative emotional response (i.e. causes negative affect) (Shrigley et al., 1988; Alsop, 1999; Fensham and Harlen, 1999; Hisschemöller and Midden, 1999; Osborne et al., 2003; Cvitanovic et al., 2014).

The two potential constraints to the informal learning of scientific information in fisheries stakeholders were investments of money and time. A limitation of resources such as time and money have been suggested to be one of the factors determining whether sectors of the public would be likely to accept scientific information/arguments (Weeks and Packard, 1997). A more recent study suggests a limitation of time also affects the uptake of scientific information among marine conservation managers (Cvitanovic et al., 2014). The findings in Chapter Four suggest that those seeking to research/model the informal learning of scientific information in natural resource stakeholders may need to base their investigations on a broader range of literature than informal learning literature alone. Informal learning literature is suitable for suggesting a direction for explorations into the informal learning of scientific information among natural resource management stakeholders. However, it is currently insufficient to capture the complexity of informal learning among these stakeholders (as explained in Chapters Three and Four) (Shrigley et al., 1988; Weeks and Packard, 1997; Alsop, 1999; Cvitanovic et al., 2014).

The variables affecting fisheries stakeholders' informal learning of scientific information were also found to have highly contextual relationships (Chapter 4). This finding corresponded well with existing mass communication and public understanding of science literature (Ham et al., 1993; Wynne, 1993; Fensham and Harlen, 1999; Ross et al., 2003; Ward and Wilkinson, 2006). The highly contextual nature of the interactions between the variables affecting fisheries stakeholders' informal learning of scientific information means that models developed to illustrate fisheries stakeholders' informal learning needs are likely only truly accurate for one particular context/topic. Mental models of any system are noted to be highly contextual and should only be considered an isolated representation of individuals' cognitions at a specific point in time (Jones et al., 2011). Therefore, a single, 'general' model is inappropriate and unlikely to be useful. Instead, developing a method to quickly elicit and construct models giving an impression of which variables are likely to be important for a given situation would be of far more value. The research presented in Chapter Five is the first step towards this objective.

Prior to the research conducted in Chapter Five, little effort had been made to illustrate the complex interactions between variables affecting the informal learning of scientific information in learners with different scientific backgrounds or agendas (as outlined in Chapters Three and Four). Few attempts were made to illustrate the way variables affecting informal learning were interacting by assigning directions, polarity (i.e. negative/positive) or relative strengths to the relationships between component variables (Chapter 3). The objective of developing a way to model the complex interactions between variables affecting fisheries stakeholders' informal learning of scientific fisheries information was achieved in Chapter Five. The contextual effects of subject matter and individuals' initial levels of interest on their willingness to informally learn new scientific information were also explored. Both of these objectives were achieved by answering the following research questions:

1. What are the factors that most significantly facilitate or limit the uptake of scientific information in recreational fishers?

2. Are the factors and relationships that facilitate or limit informal learning similar between recreational fishers?

3. Are recreational fishers' informal learning models consistent independent of their level of interest in the scientific subject matter being presented to them?

The cognitive, conative and affective dimensions (i.e. the clarity of the information, its regular usefulness, and its positive emotional content) were confirmed to have a strong driving effect on fishers' willingness to informally learn more about the subject (Chapter 5). The requirement of investments in time and money were also shown to be (in most instances) constraints to fishers' interest in further informal learning. These findings add further credibility and resolution to those from Chapter Four, suggesting that the concept of informal learning can inform the modelling of fishers' uptake of scientific fisheries science and that investments of time and money are likely to constrain that uptake.

Existing literature supports the finding that fisheries stakeholders' informal learning of scientific information is contextual and likely to vary case by case (Wynne, 1993; Sturgis and Allum, 2004; Gerhards and Schäfer, 2009; Ham, 2013). Some of the variables elicited were shown to act as drivers as opposed to constraints in specific circumstances (Chapter 5). For example, some fishers felt they would put more effort into informally learning about a topic if they had already invested time or money in the first instance. This finding suggests that at least in the case of recreational fishers' informal learning of scientific information, constraints should not be considered only as being such (Frey, 1988; Tanner, 1999; Sutton and Tobin, 2011). Rather, researchers seeking to model the informal learning of scientific information (and potentially other complex, voluntary behaviours) should be clear about the context surrounding relationships between the component variables (e.g. whether the investment of time or money is voluntary or obligatory), particularly those that have historically been chiefly considered to be constraints. It is possible that the interactions between variables affecting the informal learning of scientific information are conditional beyond the topic, and the relevance of a specific topic to the stakeholders (Chapter 5).

Recreational fishers' initial levels of interest were also found to have a strong effect on the complexity of their mental models (i.e. high levels of initial interest resulted in much more complex mental models) (Chapter 5). Mental models elicited from fishers based on topics they found most interesting were highly complex, involving many variables (often seven) with complex, multi-directional interactions and relationships between them (Chapter 5). Mental models elicited from fishers based on topics they considered least interesting were very basic, often consisting of only two or three variables and one-way relationships between those (Chapter 5). This finding suggests that informal learning, and the way it is conceptualised and modelled, can be highly dependent on individuals' initial (or likely) levels of interest in a topic.

Research designed to elicit mental models in different circumstances has had similar findings. Studies comparing mental models about human-environment interactions found that the complexity of respondents' mental models were most complex and informative when respondents were interviewed *in situ*, in the environment/system they were being asked to model (Lynam et al., 2012; Jones et al., 2014). The mental models were more complex because respondents who were *in situ* were more immediately aware, and cognisant, of the components of the systems they were being asked to model, and the interactions between those components (Lynam et al., 2012; Jones et al., 2014). It is therefore possible that the increased complexity of mental models elicited from fishers based on topics they found most interesting reflected a similar situation. Fishers ready to engage in informal learning regarding the topics they found most interesting may have become more conscious of their thought processes, and the relationships between the variables contributing to those thought processes, resulting in mental models with high levels of complexity. However, there is also the possibility that fishers' 'least interested' mental models represent the most basic criteria that need to be satisfied before more complex and involved thought processes continue. Further research beyond the scope of this thesis will be necessary to ascertain which might be the case.

The outcomes of Chapter Six were largely applied. Therefore, the research questions and the bulk of the outcomes from this chapter will be discussed in the next section. However, one finding from this chapter had potentially significant implications for the understanding of how the communication of scientific information should be approached in NRM contexts. The initial findings indicated that fisheries stakeholders used sources of scientific fisheries information at significantly different rates depending on the identity of the information source, its 'type' and the authority represented by the information source. This finding was not unexpected, and is supported by multiple studies that found individuals were likely to choose or rely upon different information sources depending on the context of the new information (Wynne, 1993; Wilson, 2000; Kiousis, 2001; Cvitanovic et al., 2014). However, further analysis indicated that a stakeholder's primary role in the fisheries management system alone was insufficient to predict which information source(s) that individual was likely to rely upon. This finding aligns well with existing mass communication frameworks and literature that stress the importance of knowing how a target audience contextualises information about a certain topic before forming a strategy (Wynne, 1993; Ross et al., 2003; Ward and Wilkinson, 2006; Ham, 2013).

That stakeholders' primary roles may be poor predictors of the information sources they are likely to rely upon is supported by mass/science communication literature. However, it is at odds with an underlying assumption of many natural resource management studies. Much of the existing natural resource management literature groups stakeholders discretely according to their primary role in a system (e.g. recreational fishers, commercial fishers, researchers, managers etc.), and treats these groups as such. Putting stakeholders into discrete groups according to their primary relationship/role in a system is prevalent even in literature that seeks to improve engagement or communication with specific stakeholder groups in natural resource management systems (Clay and Goodwin, 1995; Jacobson and McDuff, 1998; Smith et al., 1999; Kaplan and McCay, 2004; Degnbol, 2005). In some instances, grouping stakeholders in this manner might be appropriate. However, the findings of Chapter Six suggest that in future research into the communication of science in NRM, a stakeholder's primary role should not be assumed to be a good indicator of their communication/information needs.

7.3 Applied outcomes

This thesis resulted in a number of more applied outcomes and suggestions. These will be discussed in the order of their appearance in this thesis. They include:

1. A review detailing aspects of fisheries management likely to benefit from the improved communication and uptake of scientific information among fisheries stakeholders;

2. A review identifying several models and variables likely to be important for the uptake of scientific information among fisheries stakeholders;

3. Confirmation of the applicability of a set of variables important for understanding and modelling fisheries stakeholders' uptake of scientific fisheries information; a new methodology for modelling informal learning; and

4. Insights into how the communication of science to fisheries stakeholders could be improved based on the current situation.

Modern fisheries management increasingly depends on the effective transmission and uptake of scientific information among fisheries stakeholders with varied scientific backgrounds. With the increasing popularity of ecosystem-based fisheries management (EBFM) comes a need for fisheries stakeholders (e.g. managers, scientists, commercial and recreational fishers) to uptake, digest and engage with an increasingly large amount of interdisciplinary scientific information (Clay and Goodwin, 1995; Endter-Wada et al., 1998; Jacobson and McDuff, 1998; Jentoft et al., 1998; Gray and Jordan, 2010). The same is true of other branches of natural resource management (e.g. agriculture) and conservation planning, particularly in light of the increased adoption of decentralised management regimes, the active-adaptive management approach, and ever-increasing resource allocation issues (Endter-Wada et al., 1998; Ewel, 2001; Ludwig, 2001; Sturgis and Allum, 2004). There are four areas common to many NRM situations where improving the communication of scientific information between diverse stakeholder groups is likely to benefit the management of a natural resource: 1) Higher quality of submissions during public consultation; 2) Improved sense of stewardship through better engagement; 3) Greater institutional efficiency; and 4) Improved compliance. These benefits are discussed in the following three paragraphs.

Stakeholders with a greater scientific knowledge about their resource are more likely to form high resolution opinions, and make more informed decisions/comments about relevant issues (Evans and Durant, 1995; Vanclay, 2004; Granek et al., 2008; Gray and Jordan, 2010). Increasing stakeholders' scientific knowledge will enable stakeholders to further contextualise and compare new scientific information with their existing knowledge, which is likely to lead to more constructive and mutually beneficial results for all stakeholders in NRM (Chapter 2) (Weeks and Packard, 1997; Frank et al., 2009; Gray and Jordan, 2010). Widespread acceptance of management decisions based on scientific information by stakeholders, and higher rates of compliance, might be considered ideal by some. However, the benefits of effectively communicating scientific information and building an informed stakeholder community extend beyond acceptance and compliance. Constructive outcomes beneficial to management of the resource can still be achieved if stakeholders do not agree with/accept management decisions normatively or otherwise. If constructive and open discussions and discourse are fostered, resource users will be able to articulate why they do or do not consider the scientifically informed application of a particular management tool to be appropriate for the management of their local resource. A mutual understanding between the stakeholders involved (e.g. commercial and recreational fishers, and managers), and more equitable and mutually beneficial management outcomes then become possible (Bouwen and Taillieu, 2004).

A mutual understanding between stakeholder groups, and constructive discussion/discourse leading to mutually agreed upon management decisions is also likely to encourage a feeling of stewardship among stakeholders (Berkes, 2004; Granek et al., 2008; Gray and Jordan, 2010). When combined with high levels of engagement, stakeholder groups with high levels of stewardship can become more accepting of science-based, mutually agreed upon management decisions that potentially impact upon their activities (Weeks and Packard, 1997; Granek et al., 2008). In fisheries, a feeling of stewardship has also been correlated with a greater engagement in conservation activities and higher rates of volunteering among fishers, both of which are likely to benefit research oriented projects with tight budgets (Jennings and Moore, 2000; Granek et al., 2008).

Having highly engaged stakeholder groups (i.e. stakeholders who actively participate in consultation and decision-making processes in fisheries management) with a sense of stewardship also stands to benefit the management agencies themselves, particularly if they employ decentralised management regimes (e.g. co-management) (Bouwen and Taillieu, 2004). Some of the benefits include: 1) better institutional efficiency, since there is less resistance and conflict between the parties; 2) the development of management tools and making of mutually beneficial management decisions based on detailed scientific and local knowledge; 3) increased volunteerism; and 4) increased compliance (Bouwen and Taillieu, 2004; Granek et al., 2008). None of the benefits stemming from highly engaged, scientifically knowledgeable stakeholder groups described in the above paragraphs are possible without the consistent and effective communication of scientific information between the stakeholder groups involved. The applied outcomes of Chapters Five and Six contribute towards the goal of communicating scientific information consistently and effectively between the various stakeholder groups involved in NRM.

While Chapters Three and Four laid the theoretical framework for this thesis, it was in Chapters Five and Six that more applied outcomes were achieved. Chapter Five represents the first time that the fuzzy cognitive mapping approach has been applied to fisheries communication research. The new methodology developed in Chapter Five, based on a modified FCM approach, is the most applied outcome from this chapter, as opposed to the mental models themselves. The mental models presented in Chapter Five are sufficient to offer suggestions immediately useable by those seeking to communicate scientific information to recreational fishers. However, mental models are inherently dynamic and highly contextual (Jones et al., 2011). Therefore, the development of a methodology that allows the efficient and effective elicitation of useful, accurate and consistent mental models that can capture changes in attitude, understanding or cognition is a far more useful outcome for communicators and management agencies than an isolated series of mental models.

The features of the new methodology developed for Chapter Five make it highly adaptable and suitable for research in fields beyond informal learning. The methodology allowed the consistent mental modelling of a system that fishers were unfamiliar with, containing directional relationships of differing polarities and strengths, and consisting of variables hitherto unknown by participants to be elicited. This new methodology has potential applications extending beyond the modelling of informal learning, and could be applied to the modelling of other abstract systems consisting of intangible/unfamiliar variables (e.g. the development of NRM management tools).

The handouts developed for use in conjunction with this methodology, which were found to assist in maintaining the consistency of meaning during mental modelling exercises, can be found in Appendix D.

Some of the results from Chapter Five also have practical implications for those looking to study/model the informal learning of scientific information. The FCM representations of fishers' mental models based on what they found least interesting were orders of magnitude less detailed than those based on what fishers found most interesting (Chapter Five). It is therefore recommended that future studies into the informal learning/uptake of scientific information consider categorising mental models according to interviewees' initial interest levels. The disparity between fishers' mental models based on topics they found most and least interesting suggest that not doing so is likely to cause community scale models (i.e. models intended to capture stakeholders' collective perceptions of a system on a community level) to become 'normalised' through the inclusion of mental models of highly different complexity. At best, the normalised community scale models will be informative but lacking in resolution, limiting their use to communicators/management agencies. At worst, the resultant simplistic, normalised models will be misleading and be missing critical nuances that are important for the design of targeted communication strategies.

Chapter Six was designed to answer some applied research questions about the information sources stakeholders were relying upon:

1. Which information sources are most central to fisheries stakeholders' information networks?

2. Which formats are fisheries stakeholders relying more heavily upon?

3. Which authorities do the information sources fisheries stakeholders depend upon represent?

4. How can those stakeholders who are more remote in the information network be reached more effectively?

5. How does a stakeholder's primary role in the fisheries system affect their reliance on the various information sources?

Answering those research questions led to insights that are potentially of immediate use to those designing communication programs aimed at fisheries stakeholders. Scientists and commercial and recreational fishers appeared to rely more heavily upon direct interactions with scientists for scientific information, while managers relied more heavily on government publications and primary literature. Scientists appeared to be the most popular information source, with primary literature being second most popular (mostly due to its heavy usage by scientists and managers). Of all the individual resources listed in this study, scientific information sourced directly from scientists had the greatest reach across the range of stakeholder groups surveyed (i.e. managers, scientists and commercial and recreational fishers). This finding was somewhat unexpected, and might be partially explained by survey bias (i.e. highly avid fishers who are most likely to answer surveys are also the most likely to have past interactions with scientists) (Ditton et al., 1992; McInnes, 2006). Issues related to time might also have been a contributing factor. Multiple stakeholders (mostly managers) preferred to contact scientists directly, because they felt it took too long for new research to be published in scientific literature (Chapter 4). Issues relating to time have also been shown to motivate conservation planners' preferences for/reliance upon information sources (Cvitanovic et al., 2014). Contacting scientists might also be seen as the best way to access accurate scientific information without reading and digesting highly technical scientific journal articles (Cvitanovic et al., 2014). If this finding can be verified by future studies, there are some positive implications for those designing communication strategies aimed at a diverse range of fisheries stakeholders.

These positive implications include: the ability to reach a broad range of fisheries stakeholders, better quality control, and the potential for major cost reductions. The reliance of a suite of stakeholder groups upon government and academic sources for scientific information might represent a convenient and ready opportunity for transparent, open discourse and efforts to improve the engagement of the various stakeholder groups (Pomeroy and Berkes, 1997; Kaplan and McCay, 2004). From a management agency's perspective, the reliance of fisheries stakeholders on government and academic sectors means that quality control of the scientific information, and control over the messaging, might be less of an issue. Management agencies increasing their volume of scientific fisheries outreach might also have less of a need to negotiate with, or pay second or third parties (e.g. advertising agencies, social media consultants, journalistic publications etc.) to reach, a broad range of their stakeholders.

Several applied recommendations can be made from the findings of this thesis for those designing communication programs aimed at fisheries stakeholders. Firstly, stakeholders' primary roles in fisheries management do not necessarily dictate their communication and information needs. It is far better to first establish the target audience depending on the intentions/purpose of the communication, and then tailor the strategies to suit once the context of the information to the target audience(s) can be established.

Secondly, the role of scientists in scientific fisheries outreach should not be underestimated. A diverse range of stakeholders seem to acquire new scientific information directly from scientists. Therefore, it is recommended that opportunities to do so should at the very least be maintained, if not facilitated and increased in number. Those looking to escalate their efforts in scientific fisheries outreach might consider conducting regular workshops/public presentations where stakeholders who would not normally have the opportunity to interact with scientists directly can be allowed to do so. There have been many instances where scientists' informal interactions with sectors of the public, and the development of relationships between the two have contributed towards an increase in uptake and engagement with scientific information and projects in fisheries, and other fields (including physics) (McDuff, 1999; Hart, 2002; Granek et al., 2005; Angermeier, 2007; Martin-Semperere et al., 2008; Frank et al., 2009). The increasing global adoption of social media has also made it possible for scientists to interact, share imagery and ideas, and form informal relationships with sectors of the public without huge investments of time or money. Though social media was not identified as a source of scientific information for fisheries stakeholders, this might be due to a limited sample size, or a lack of awareness among interviewees of suitable content/content providers. At worst social media represents a convenient, cost-effective (albeit potentially less effective) alternative to running public workshops/lectures etc. for scientists and management agencies alike.

Thirdly, communicators should maintain as much flexibility and adaptability as possible. Because the way fisheries stakeholders cognitively engage with and physically access scientific information appears to be highly contextual (and, therefore, highly changeable), communicators should avoid restricting their efforts to a single or small number of formats (i.e. print media, direct contact, scientific literature etc.), modes of messaging, or publication avenues (Chapters 4,5 & 6). The findings from Chapters Four and Five emphasise the fact that the information must be presented clearly, without causing cognitive dissonance (i.e. where new information is at odds with their existing knowledge, beliefs, or opinions), appear regularly useful and, ideally, have a positive emotion associated with it (Aronson, 1969). The method of presentation, and the tailoring of the messaging should adhere to those criteria. The format and publishing avenue should be selected based on the context of the information, its implications to the target audience, and the audience's needs (e.g. we cannot assume that all recreational fishers will prefer the information in the same format regardless of the content). Likewise, the messaging should be carefully tailored according to the target stakeholders, and the context of the information (in particular, its relevance to stakeholders' activities, and their previous experiences with similar information/information sources) (Lakoff, 2010; Campbell and Kay, 2014). Finally, the information should require minimal (if any) obligatory, monetary or temporal investment on the part of the target audience.

7.4 Study limitations and future research

The chapters of this thesis represent a series of exploratory studies testing the applicability of concepts from the existing literature to the communication of scientific information to fisheries stakeholders. Therefore, the studies conducted here had relatively small population sizes, and the results should be interpreted with this in mind. The results should not be interpreted as being definitive or absolute, but as evidence for the efficacy of the methodologies developed and as suggestions of trends that warrant further investigation. Larger scale studies involving a more representative sample of all the stakeholders studied here (i.e. managers, scientists, commercial and recreational fishers) will be necessary to further confirm/refute the findings presented in this thesis.

With reference to Chapter Five in particular, care should be taken when interpreting mental models. Mental models should not be treated as complete, unchanging representations of individuals' perceptions of a system (Jones et al., 2011). Mental models are incomplete representations of how individuals perceive a system at a specific point in time (Jones et al., 2011). As individuals' understandings of, or attitudes towards, a system change, their mental models are also likely to change (Jones et al., 2011). Therefore, it is recommended that the mental models from Chapter Five, and the relationships portrayed within them are interpreted as guidelines and suggestions. It is also recommended that those interested in constructing mental models to facilitate/inform strategic efforts to communicate with wider fisheries stakeholders apply the methodology developed in Chapter Five to their specific target audience and circumstances to elicit mental models more specifically relevant to their needs. For example, it is unlikely that interest in informally learning scientific fisheries information will be affected by the same suite of variables in managers and scientists, as it is in recreational fishers (Boud and Middleton, 2003; Cvitanovic et al., 2014).

The methodology as applied in Chapter Five is recognised as being unable to uncover why fishers' mental models differed so markedly depending on their initial interests in a topic. It was only possible to conclude that mental models based on what fishers' were most interested in were many times more complex than those based on what they were least interested in. The methodology used was not designed to generate the information necessary to conclude whether recreational fishers' initial interest in learning about a topic made them more conscious of their complex/elaborate thought processes. Correspondingly, it was not possible to confirm whether mental models based on topics fishers were least interested in represented the most basic criteria that needed to be satisfied before further thought was expended, or whether some other mechanism was at play. Therefore, it is suggested that future research seeking to model informal learning, or other behaviours including complex, contextual thought processes, might benefit from including lines of questioning about which considerations are foremost in interviewees' minds (and potentially why) before expanding onto relationships between other, more remote variables.

The findings from Chapter Six suggesting that stakeholders' primary roles (i.e. whether they are managers, scientists, or commercial or recreational fishers) are poor indicators of which information sources they rely upon has significant implications for future research. At the very least, this finding suggests that targeting specific stakeholder groups is more complex than publishing the new information in those information source(s) that the various stakeholder groups have historically relied upon. Future research into the communication of scientific information to fisheries stakeholders might benefit from investigations into which characteristics/variables aside from their primary role in fisheries management could be better indicators of stakeholders' reliance on certain information sources. The current literature suggests that these indicators might be highly contextual, and attempting to correlate the relevance of the information to stakeholders' activities with the sources they are accessing the information through might be a good starting point (Berkenkotter and Huckin, 1995; Boud and Middleton, 2003; Cvitanovic et al., 2014). The relevance of new information to individuals' activities has been correlated with many behaviours and attitudes related to the uptake of scientific information (Shrigley et al., 1988; Ditton et al., 1992; Levy-Leblond, 1992; Weeks and Packard, 1997; Alsop, 1999; Li et al., 2010; Cvitanovic et al., 2014). The combination of a detailed questionnaire designed to gather information about context (i.e. the relationship between the participant and the topic/message), the modified FCM methodology presented in Chapter Five (to model relationships between the variables), and the network analysis techniques used in Chapter Six (to test for consistency or lack thereof between the models elicited) might be one approach that future researchers could take.

7.5 Closing remarks

The effective and efficient communication of scientific information to and between stakeholders has many benefits for the management of any natural resource. Despite these benefits, relatively few studies have aimed to understand how scientific information can be communicated to natural resource stakeholders more effectively. Scientifically defensible communication strategies aimed at various stakeholders can be developed through the application of theories from informal/formal learning, psychology, public understanding of science, and mass communication literature. This thesis aimed to demonstrate how the application of novel methods guided by learnings from this literature can result in immediately useable outcomes applicable to the design of communication strategies aimed at diverse stakeholders. Useable, scientifically defensible variables affecting stakeholders' informal learning of scientific information, and mental models illustrating the relationships between those variables, were elicited. The communication of scientific information to natural resource stakeholders stands to benefit from an interdisciplinary approach, especially as the relationships between stakeholders and scientific information, and the ways they source that information, continue to change and evolve. I hope that this thesis and the publications in the primary literature that will come from it, help stimulate further awareness, interest, theory development and research on these important and under-studied issues.

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Wynne, B. (1992) Misunderstood misunderstanding: Social identities and public uptake of science. *Public Understanding of Science* 1, 281-304.

Wynne, B. (1993) Public uptake of science: A case for insitutional reflexivity. *Public Understanding of Science* 2, 321-337.

Appendix A: Examples of fisheries science for semi-structured interviews

CYCLONES AND REEF FISH CATCH

(Tobin, A., Schlaff, A., Tobin, R., Penny, A., Ayling, T., Ayling, A., Krause, B., Welch, D., Sutton, S., Sawynok B., Marshall, N., Marshall, P., Maynard, J. 2010)

Catch rates of red throat emperor (*Lethrinus miniatus*) and common coral trout (*Plectropomus leopardus*) are affected by severe weather. The 'catch per unit effort' was compared between the years of cyclone Justin and Hamish (1997 and 2009) and those leading up to them. Both Justin and Hamish appeared to affect the catch rates of both red throat emperor and common coral trout. Their impacts however, were different. Red throat emperor catches increased in Northern areas of the GBR following both tropical cyclones. In Southern areas, catch rates were stable over the years, but dropped sharply after cyclone Hamish. Coral trout catch rates dropped after both tropical cyclones. The difference between the two cyclones was that a cool water anomaly followed Justin, while warm water followed Hamish. Justin also did only minor damage to the reef, while Hamish did significant damage. It is possible that red throat emperor, which naturally roam between reefs and shoals, were encouraged to come inshore with the cooler water following Justin, while staying out in deeper water after Hamish. Coral trout, being very site-attached fish, were likely present, but were 'sulking' after both cyclones.

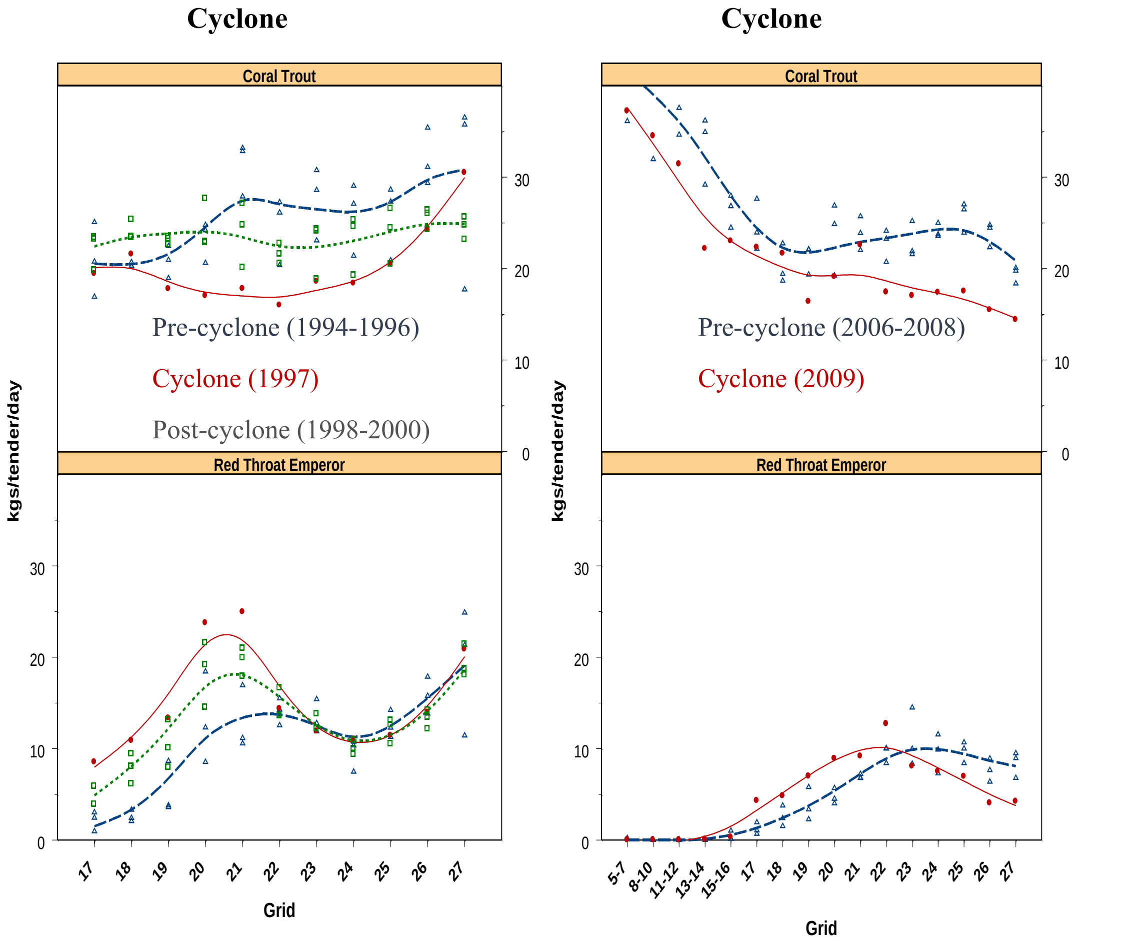

Figure 1. Coral trout and red throat emperor catch comparisons for cyclone Justin and Hamish. Lines indicate changes in catch rates. Grid numbers denote fishery grids set out by Queensland Fisheries.

THE EFFECTS OF MARINE PARKS ON RESOURCE USE

(De Freitas, D. M., 2010)

In 2004, the amount of 'no fishing' green zones in the GBR region was increased from 5-33% of its total area. In 2006-2007, 132 recreational fishers from Townsville and Rockhampton were asked to draw their favourite fishing areas from before the 2004 Zoning Plan and after the Zoning Plan on a map. Respondents' maps were super-imposed on top of one another to gain an idea of whether fishers' efforts were concentrated in certain areas. The results indicated that fishers' activities were affected by the Zoning Plan. Fishers had relatively large areas to spread out over prior to the 2004 Zoning Plan. Therefore, their efforts were only clustered in relatively few areas. After 2004, the number of areas where fishers concentrated their efforts increased, while the size of these areas decreased on average. Fishers' efforts also appeared to become more concentrated in areas where green zones took up a large portion of near-shore reef/fishing area.

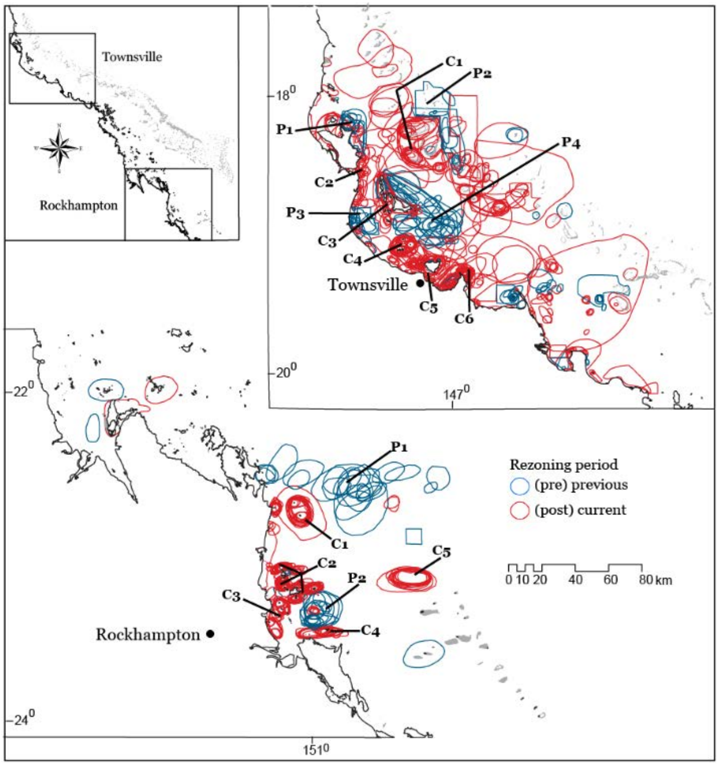

Figure 2. The blue shapes labelled with a "P" indicate areas of where respondents fished before the 2004 Zoning Plan. The red shapes labelled with a "C" indicate areas of current fishing activity at the time of the survey (2006-2007). The numbers are there to label clusters of fishing activity i.e. P1 – indicates the first cluster of areas of where respondents fished prior to the 2004 Zoning Plan.

Appendix B: Semi-structured questionnaire

Hi, how's your morning/afternoon/evening been? My name's Owen, and thanks for helping me out with this survey. What I'm trying to find out today is how people make decisions about whether a piece of new information about fisheries is worth keeping. By that, I mean how you might decide to 'learn' about fisheries or fishing (or not) and maybe a little about how you go about learning about fisheries. The questions I'm going to be asking you have no right or wrong answer, and I'm interested in anything you might have to add along the way. If you yourself have any questions, don't hesitate to ask. Let's get into it, shall we?

During this survey, I'll be asking you about 'fisheries relevant information' a lot. By 'fisheries relevant information', I mean any scientific information that contributes to the management of fisheries.

1. ***First, I'll just ask a few questions so I can get an idea of how you relate to the fishery and the information surrounding its management***

1a. How old are you?

1b. How do you feel you primarily relate to the fishery? (i.e. Which primary role do you feel you play? are you a fisher, researcher, manager etc. etc.)

1c. How long have you been fishing for?

1d. How important is fishing/working in fisheries to you?

2. ***Here is an example of fisheries relevant information (Hand interviewee informative paragraphs about fin fish fishery stock assessment). I'll give you a few minutes so you can read over the article, which is summarised from a published paper***

2a. Knowing that I'm not testing you, but rather how useful the information is, do you find the article understandable? (Can you tell me what it says?)

2b. Have you come across this kind of information before?

2c. What sort of conclusions can you reach (or what messages did you get) from reading the article?

2d. Do you find such information useful in terms of your interests, fishing activities, your job/career? (Probe – if they favour one over the other)

2e. Why/Why not?

2f. What makes this information relevant/irrelevant to you?

3. Next, I would like you to consider this summary article about fisher use patterns in the Great Barrier Reef. (Hand interviewee informative paragraphs). I'll give you a few minutes so you can read over the article.

3a. Do you find the article understandable? (Can you tell me what it says?)

3b. Have you come across this kind of information before?

3c. What sort of conclusions can you reach from reading the article?

3d. Do you find such information useful in terms of your interests, fishing activities, your job/career? (Probe – if they favour one over the other)

3e. Why/Why not?

3f. What makes this information relevant/irrelevant to you?

4. The following questions are about sources of information.

4a. After seeing these two examples, have you come across this kind of information before?

4b. Can you tell me what kinds of fisheries relevant information you might be interested in?

4c. What are your main sources of fisheries relevant information?

4d. Do you actively seek out fisheries relevant information, or just come across it most of the time (Probe - How?)?

4e. Why do you use the sources that you do?

4f. Which sources do you consider to be the most trustworthy? Why?

4g. What did you find out from [the radio/the news on TV/Fishing shows on TV (Stick to the first 3/5 they mention)]?

4h. Where else do your friends/peers get their information that deals with fishing/fisheries?

4i. Which sources are you aware of and do not use? Why?

4j. Which sources do you not trust? Why? [Probe: commercial/rec fishers, researchers, managers, govt vs. non-govt etc.]

5. ***The following questions are about presentation and uptake of information.***

5a. Can you remember a time when fisheries relevant information was presented well (i.e. interestingly and understandably)?

5b. Can you remember a time when fisheries relevant information was presented very poorly (i.e. not understandable, or interesting)?

5c. Can you remember a time where you discovered some fisheries relevant information which changed the way you fish? If yes, can you tell me a bit about that experience? E.g. What was the single most important piece if information that led to your changed practice?

5d. Have your past experiences ever affected your attitude towards a new piece of fisheries relevant information? Can we talk about that in a bit more detail?

5e. What might influence your ability to trust or not trust a new piece of fisheries relevant information?

6. ***Thanks for your patience so far, I just have a little quiz for you now. Don't worry about the correctness of your answers; the first answers that spring to mind are the ones I'm interested in. These interviews are also anonymous. Any help you give me here would be great.***

Rec fishers and Commercial fishers:

6a. OK, could you please explain what fishing size restrictions are?

6b. Are there different size restrictions for different fish? Why?

6c. Why do you believe size restrictions are in place?

6d. What would you change about the current size restrictions?

Managers/researchers:

6i. Could you please explain the concept of marine park zoning to me?

6j. What do all the different zones in the GBR region denote?

6k. Why do you think the zones are in place?

6l. What would you change about the current zones/zoning practices?

7. ***Just one last set of questions about how you might like to contribute to fisheries management.***

7a. What do you think it means to become involved in fisheries management?

7b. How important do you think it is for people to become more informed about fisheries when becoming involved in fisheries management?

7c. Have you ever been involved in fisheries management (i.e. public consultation, written a submission etc.)? Can we discuss that a little bit?

7d. How do you feel being better informed about fisheries would affect the likelihood of you becoming involved in fisheries management? Why?

OK, that's it. Thank you for your time and all your help. If you have any further questions, do feel free to give me a call or send me an email.

Appendix C: Examples of fisheries science for FCM approach to mental modelling

Feeding patterns of QLD school and spotted mackerel

The stomach contents of 226 Queensland school mackerel and 320 spotted mackerel were examined over a period of two and a half years along the east coast of Queensland. These fish were caught using line and net methods. School mackerel were found to have a more diverse diet than spotted mackerel. Spotted mackerel were found to eat pilchards, anchovies and herring almost exclusively. School mackerel were more opportunistic, especially during summer, also eating other fish as well as prawns and squid. The peak feeding periods for the Queensland school mackerel fall on late autumn and early winter when they move inshore, and during spring, just prior to spawning. Spotted mackerel have a peak of feeding activity during July while preparing to spawn in North Queensland waters. They are however in the area from late winter through to early spring.

Reference:

Begg, G. A., & Hopper, G. A. (1997). Feeding patterns of school mackerel (Scomberomorus queenslandicus) and spotted mackerel (S. munroi) in Queensland east-coast waters. *Marine and freshwater research*, *48*(7), 565-571.

Anti-angling philosophy and its relevance to recreational fisheries

Over the last decade, there has been a distinct increase in the moral debate concerning recreational fishing. Two of the most frequently heard objections are that it is no longer strictly necessary for people to fish in the developed world, and that anglers cause fish pain and suffering. Surveys of thousands of citizens found that in Austria, Germany, England, Wales, Finland and the USA, around 20% of the non-angling public said that catch and release fishing caused unnecessary pain and suffering to fish. There was less disapproval of fishing for food, and a majority of the people surveyed agreed that fishing was a healthy leisure activity. What we need to do is effectively communicate to the public about the realities of fishing, not just in terms of the social and economic benefits, but also what we currently know about the capability of fish to feel pain and what changes their behaviour.

Reference:

Arlinghaus, R., Schwab, A., Riepe, C., & Teel, T. (2012). A primer on anti-angling philosophy and its relevance for recreational fisheries in urbanized societies. *Fisheries*, *37*(4), 153-164.

Shifts in movement and habitat use of juvenile pigeye sharks in a tropical nearshore region

Forty three juvenile pigeye sharks were tagged with 'pingers' over two years. In tracking these sharks, it was found that juvenile pigeye sharks spent long periods in shallow, turbid habitats. All the tagged sharks' home ranges were centred in areas near creek and river mouths. The larger juveniles used larger areas and moved outside of their home range more often. The sharks' movements were related to the tidal cycle, but changes in water depth seemed to influence the younger sharks more strongly as they spent more time in the shallows.

Reference:

Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Tobin, A. J., & Moloney, J. (2011). Ontogenetic shifts in movement and habitat use of juvenile pigeye sharks Carcharhinus amboinensis in a tropical nearshore region. *Mar Ecol Prog Ser*, *425*, 233-246.

Appendix D: Handout to anchor and objectify informal learning variables

This handout is designed to help you during the interview.

The bold titles are the names of the variables I will be questioning you about.

Below each title, there is a short description of what each variable means.

In the square brackets, you will find a way to visualise how each variable might increase or decrease (This will become important for the later questions). Your answers do **NOT** have to be given according to those values.

The last item on this handout includes the scale I'll be asking you to rate the effect of each variable with.

Interest in memorising or further investigating this piece of information

How willing you are to either memorise or further investigate this piece of information?

[*Very much so; Moderately so; Undecided; Probably not; Definitely not*]

How much sense it makes

How the information fits in with your present knowledge. Whether you can understand the information. Whether the information makes enough sense to you that you could see a use for it (for anybody).

[*Measured by what percentage of it can you understand, and makes sense to you*]

Regular usefulness

How useful you think the information would be to YOU. Whether you see yourself using the information regularly enough that you would want to either memorise it or further pursue it.

[*Measured by how many times you might see yourself using the information over a week, month, year etc.*]

Positive emotion (Good feeling/will?)

How good you feel about where the information is coming from or what your family and friends think of it.

[*Measured by the number of people you know including yourself who approve of the information*]

Negative emotion (Upsetting?)

Whether the information or its source or format upset you, your friends or your family.

[*Measured by the number of people including yourself who do not approve*]

Investment in time

How much time you are willing to put into learning more about the new piece of information.

[*Measured by the number of hours you might be willing to dedicate to learning about this new information*]

Investment in money

How much money you might be willing to spend to get access to the information or related information.

[*Measured in terms of dollars*]

The scale

When I ask how each variable might influence your willingness to memorise or further pursue the information at hand, please give your answer on this scale:

Very negatively

Moderately negative

Slightly negative

Not at all

Slightly positively

Moderately positively

Very positively