Species conservation in a complex socio-ecological system: Irrawaddy dolphins, *Orcaella brevirostris* in Chilika Lagoon, India

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STATEMENT ON THE CONTRIBUTION OF OTHERS

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Sutaria, D., and H. Marsh. (In Preparation). Assessing conservation status under Uncertainty - the Irrawaddy dolphin (*Orcaella brevirostris*) in Chilika Lagoon, India.

ABSTRACT

Endangered species conservation requires many lines of inquiry to provide the evidence required for a holistic approach to conservation planning. The main aim of my research was to inform the conservation planning of endangered species found in developing countries. It is my thesis that species conservation in developing countries is a socio-ecological issue and that the role of conservation science is limited without the inquiry of human dimensions and their influence on conservation outcomes. I studied the Irrawaddy dolphin, *Orcaella brevirostris* in Chilika Lagoon, India, as a case study to exemplify this problem and to validate a solution.

The Irrawaddy dolphin has been assessed as 'Data Deficient' by the IUCN at a global scale, but five freshwater and brackish water subpopulations are Critically Endangered. The species is found in isolated, patchy populations and tends to occupy shallow, muddy coastal waters, enclosed bays and lagoons, or freshwater river systems. In the region of the Indian subcontinent, the species has been recorded from Chilika Lagoon on the east coast of India, and in the tributaries of the Sunderbans Delta, West Bengal. My thesis informs current knowledge regarding Irrawaddy dolphins and produces new results for the population in Chilika Lagoon. The absence of recent Irrawaddy dolphin carcasses along the coast of Orissa or of sightings of live Irrawaddy dolphins during a vessel based survey of the coast suggests that the population in Chilika Lagoon is isolated and should be treated as a conservation target.

Chilika Lagoon is a RAMSAR site supporting a population of more than 200,000 people. A preservationist strategy which completely excludes people from protected areas by relocation programs is neither feasible nor culturally advisable in the case of Chilika Lagoon. To incorporate dolphin conservation and sustainable use of resources into the daily lives of the people requires strategies that consider the social circumstance of the communities, and their perceptions. I interviewed fishers from 44 villages to collect local information and knowledge regarding Chilika and its dolphins. The results indicate a significant decrease in the range of the dolphins within the Lagoon and suggest that the major causes for mortality in dolphins are fishing nets, habitat loss and motorized boats. I found that fishers' perception of dolphins differed primarily with the location of their village, suggesting that experience plays a role in developing affiliation. Local people in Chilika like to observe dolphins, like to have them in their vicinity when they go fishing and to an extent revere dolphins. These are good signs for conservation and for future dialogue in the fields of awareness building, innovative solutions and co-operation towards conservation aims. I also found that the economic well being of stakeholders is dependent on fish catch and there are conflicting perceptions towards the management of fishery resources in Chilika among local communities and between policy makers and local communities. These issues of common property management are likely to limit the success of social programs, including conservation initiatives.

I identified 80 individual dolphins using natural marks and variously estimated the abundance of the population using Mark-Recapture analysis as 109 to112 individuals at CV=0.07 (closed models); and 140 at CV=0.25 (open models), based on surveys from November 2004 to December 2006. The power analysis indicated that a rate of 5% decrease per year would take 7 years to detect; even a decline of 20% would take 3 years to detect using the same survey protocols, by which time a population of 112 animals will have become reduced to 57 animals. It is thus critical that the monitoring of the population use a robust standard protocol which includes an assessment of uncertainty. I suggest that owing to the small population size, long-lasting natural marks, enclosed nature of the study area and already present photo-identification catalogue, the Mark-Recapture methodology would be feasible and appropriate for future monitoring of the population.

The total Extent of Occurrence for Irrawaddy dolphins in Chilika was <330km^2; and the Area of Occupancy was <131km^2, both of which are less than half of the available habitat. The dolphins concentrate their use in two core areas in the Lagoon: the Outer Channel (12km^2) and the South-Central Sector (49km^2). The site fidelity of individual dolphins is high with more than 80% of the individuals remaining within 10km of their mean centre. Home range estimates vary from 1.7km^2 to 186km^2 for individuals sighted more than nine

times between 2004 and 2006 with a large overlap in home ranges. The quality and carrying capacity of the habitat thus play an important role in the long term survival and health of dolphins in Chilika.

The analysis of group size and behavior suggested that average group sizes were small (3-4 dolphins) with 25% of the observations consisting of solitary individuals. Group size did not differ significantly among the behavioral states of feeding, milling and traveling, but were significantly larger when the dolphins were socializing and resting. The dolphins were found across the entire range of water depths and salinity, and group sizes varied little with changes in measured environmental variables. The core areas appear to be the major feeding grounds for Irrawaddy dolphins in Chilika Lagoon, with feeding, milling and socializing dominating the day-time activity budget.

A preliminary analysis of social structure for Irrawaddy dolphins suggested that the associations among dolphins in Chilika Lagoon were weaker and more fluid than those observed in other populations of *Orcaella,* which live in stable societies. Out of the 48 individuals analyzed, only 14 individuals showed an association index ≥ 0.5. Few individuals did not associate with any other individuals, whereas most individuals associated loosely with all other individuals.

Based on all the data, both the conventional IUCN assessment and the RAMAS Red List assessment indicate that the population of Irrawaddy dolphins in Chilika Lagoon should be listed as Critically Endangered. This decision would be precautionary rather than evidentiary and not without uncertainty.

I investigated the locally run dolphin-watching industry, an established occupation in the Outer Channel, to assess ways in which the industry could help in conservation of dolphins. Ideally, the industry would strengthen conservation programs through local economic development and income generation. Interviews with tourists suggest that boat drivers turn their engines off in the presence of dolphins indicating that most boat drivers have gradually become aware that dolphins stay around their boats longer if the engines are off. Results from a questionnaire survey of tourist operators show that local communities are aware of the risks faced by dolphins from the tourism operations, and could distinguish factors that cause disturbance and mortality. Respondents suggested that removal of obstructions to dolphin movements was the most effective conservation strategy, as it would increase the amount of space available to dolphins and ease their movement between the Outer Channel and South Central sectors. This strategy would also increase the free movement of roe and fish into the Lagoon. The strength of the tourism linkage is very similar to that of the fisheries with communities in the Outer Channel of Chilika but conservation outcomes from the linkage have not yet been realized and would require responsible social and ecological planning to make the industry sustainable. There are currently no set approach distance and no limits on the number of boats allowed around a group of dolphins, or on the number of boats allowed to go dolphin watching per day. Conservation practitioners need to increase awareness amongst local stakeholders to help recognize the benefits of conservation goals, and the linkage between tourism livelihood and dolphin persistence.

My research demonstrates that conservation planners require evidence from both ecological and socio-economic lines of inquiry. Biological information is necessary, but not sufficient to conserve Irrawaddy dolphins in Chilika. Dolphin conservation is inextricably linked to natural resource management and system-level management. One of the main limitations to successful conservation is the mismatch between top-down 'expert opinion' - based management decisions and the preferences of the stakeholders who actually operate at the scale of the system being managed. Given the Critically Endangered status of the Irrawaddy dolphin population of Chilika and the cultural and social importance of dolphins, a long term conservation program inclusive of social and ecological research using an action-research model should be the future goal of conservation practice in Chilika. I propose a conservation model which functions with the support of policy makers to reduce cross-scale conflict, rather than as a top-down enforcer of protection. Given the range of natural and induced ecological changes in the Chilika system over the past decades and the changes anticipated in this era of climate change, sustaining habitat quality planning for the Chilika system.

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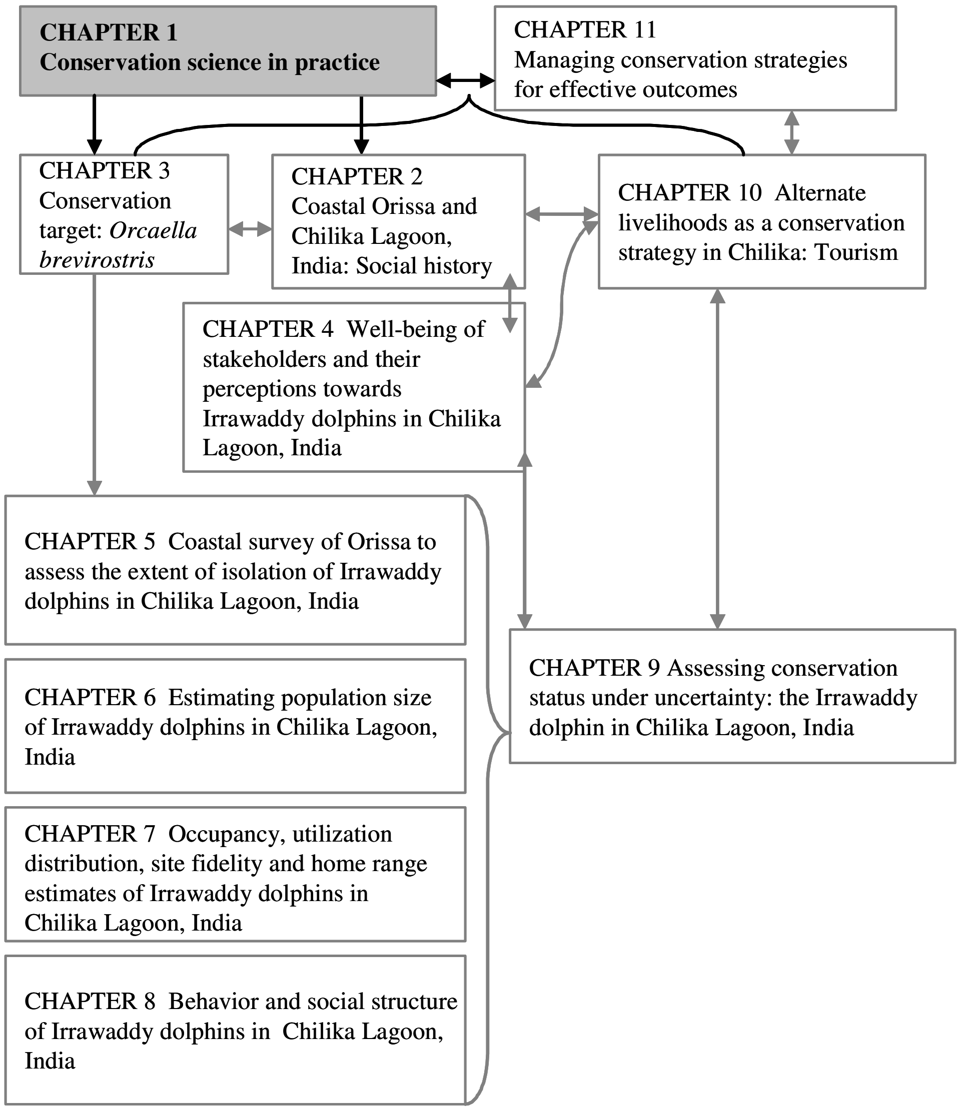
1 CONSERVATION SCIENCE IN PRACTICE



In Chapter 1, I review the history of the conservation paradigm as the context for my thesis. In 2008, the World Conservation Union (IUCN) listed 25% (n=1139) of all known mammalian species (n=5487) as globally Threatened (Schipper et al. 2008) including 36% (n=30) of the 120 marine mammal species. Burgeoning infrastructure development in urban and rural areas especially coastal areas, expanding cities and growing human populations in developing countries necessitate biodiversity, species and resource management across local, regional, national and international scales (Halpern et al. 2008). In this thesis, I use the case of a 'small population' of a slow reproducing marine mammal species, the

Irrawaddy dolphin *Orcaella brevirostris,* to explore factors which underpin initiatives to increase the likelihood of persistence of endangered species in human dominated habitats in the developing world. In this chapter, I offer a conceptual framework for my study and suggest that the effective application of conservation science is limited without a holistic view of the socio-ecological system and the involvement of local stakeholders in its implementation.

"The emergence of ecology has placed the economic biologist in a peculiar dilemma: with one hand he points out the accumulated findings of his search for utility, or lack of utility, in this or that species; with the other he lifts the veil from a biota so complex, so conditioned by interwoven cooperating and competitions, that no man can say where utility begins or ends. No species can be "rated" without the tongue in the cheek; the old categories of "useful" and "harmful" have validity only as conditioned by time, place, and circumstance. The only sure conclusion is that the biota as a whole is useful, and [the] biota includes not only plants and animals, but soils and waters as well, but health is more than a sufficiency of these components. It is a state of vigorous self-renewal in each of them, and in all collectively"

(Leopold 1939:727-730)

1.1. Introduction

The history and development of the conservation paradigm and of changing governance systems are two sides of the same coin (Agrawal & Ostrom 2006). The dominance of top down intervention by central governance structures to prevent the loss of biodiversity and habitats, and the extinction of species before they were even scientifically described, led to the large scale movement of 'preservationist conservation' in the 1970s. 'Protected areas' that excluded all or lethal human activities (IUCN 1994) were typically the first course of action (Redford & Sanderson 2000) (Salafsky & Wollenberg 2000). This approach is the irrevocable product of the preservationist paradigm, and typically involves the relocation of human communities from terrestrial protected areas (Karanth & Madhusudan 1997; McLean et al. 2003; Rangarajan & Shahabuddin 2006), whereas marine protected areas typically ban the harvest of certain threatened species or exclude certain kinds of fishing and developmental activities(Agardy 1994; Carr 2000). Developing countries lack the space and/or financial resources to relocate vast human populations from protected areas. Whether practiced for industrial development or wildlife protection, the relocation of people in India has invoked considerable resistance and has been the cause for great environmental movements at the stakeholder level (Martinez-Aliers 2002). In contrast, relocation and restructuring has been more feasible in developed countries like the USA, Australia and Europe that have the financial resources to provide alternate livelihood options.

The first national park was declared in the USA in the late nineteenth century and this initiative has been imitated worldwide. In 1958, the IUCN first attempted to categorize the different types of Protected Areas prevalent in Europe and the USA during the early 20th century, all of which excluded human activities. The protected area paradigm subsequently became the bastion for conservation planning (Adams et al. 2004). By 2005, over 100,000 protected areas had been declared globally in both developed and developing countries, using similar sets of guidelines for a diverse range of social, cultural and economical regions and scales. By the 1970s, the protected area approach was increasingly challenged by human communities that had traditional cultural ties to or obtained economic benefits from the natural resources being managed (Rao & Geisler 1990; Smith & Marsh 1990; Agrawal & Redford 2006). The idea that protected areas needed to be sensitive to local belief systems and economic needs gained momentum in the late 1970s. Today, the IUCN has a protected area classification system administered by the World Commission of Protected Areas (Holdgate 1999; Ravenel & Redford 2005). The classification encompasses six types of protected areas, two of which still completely exclude all human activities while the rest are inclusive of human activities to different degrees.

The concept of 'reserves' or 'biospheres' with spatial zonation that provides local communities with alternate or substitute forms of livelihood options in buffer zones, while protecting core areas of biodiversity, was first implemented in the late 1970s (Sayer 1991). These management regimes were intended as a compromise between livelihood, traditional rights and conservation objectives. By the 1980s, the conservation paradigm had started changing from total exclusion to the inclusion of people in the conservation process, and the community-based conservation paradigm became the topic of much debate in conservation circles (Wells & Brandon 1992; Western et al. 1994; Wilshusen et al. 2002).

Direct (e.g. fishing, species based tourism) or indirect dependence (e.g. market forces) of consumers and resource extractors on the resource to be conserved has been suggested as the mainstay of community-based conservation (Agrawal & Gibson 1999; Salafsky & Wollenberg 2000). In many developing nations, even this concept, which explicitly recognizes the linkage between local communities and their environment has not led to successful outcomes in conserving individual species or biodiversity (Brandon et al. 1998).

In India, two large scale conservation projects- 'Project Tiger' (MoEF2001) and 'Project Elephant' (MoEF 1992) have been through the cycle of conservation approaches from the 'preservationist' method of conservation to a system of reserves more inclusive of human activities. There are 27 protected areas covering 37000 km^2 where tigers are protected, 25 elephant reserves covering more than 58000km^2 and 64 protected areas where elephants are found. Nonetheless both Project Elephant and Project Tiger, have proven unsuccessful in India with both species dwindling rapidly (Karanth & Madhusudan 1997; Sukumar 2006). Both these projects use spatial reserves with core areas and buffer zones as the strategy for species conservation. In the marine environment, marine sanctuaries and marine biosphere Reserves have implemented no fishing zones such as the Gulf of Mannar Biosphere Reserve which aims to conserve biodiversity or the Gahirmatha Marine Sanctuary that aims to conserve species like the olive ridley turtle (*Lepidochelys olivaceae*) off the coast of Orissa. This approach has caused much dissatisfaction and unrest in the local human communities dependant on marine resources from these areas (Ilangakoon et al. 2008; Mathew 2004; Shanker 2004).

Much discussion has ensued amongst conservationists, ecologists, managers and social scientists about the apparent reasons for the failure of conservation programs especially given the large amount of resources invested in this process. Non-compliance by local communities, little or no enforcement by policing agencies, intervention of external profiting enterprises and illegal immigrants benefiting from resources otherwise not available to local communities are some of the reasons commonly identified for the failure of protected areas and reserves (Brandon & Wells 1992; Madhusudan & Shankar Raman 2003; Ilangakoon et al. 2008).

Most of the problems associated with local communities represent a lack of collaborative space in the governance system and conservation action model. Such a collaborative space allows problem solving and learning to be a two-way process (Carlsson & Berkes 2005). The exclusion of human communities from the conservation process and the lack of operational 'conservation plans' with an action-research framework has thus severely limited the success of conservation practice.

Many conservation practitioners now consider that effective conservation planning must include human participation and co-management of resources, and be built on a generic framework of action-research and social learning, that assesses outcomes including both successes and failures (Bright et al. 2000; Margules & Pressey 2000; Riley et al. 2002; Salafsky et al. 2002; Schusler et al. 2003; Knight et al. 2006). In the following sections, I present the main aim and objectives of my thesis and consider the conceptual basis for my research in that context.

1.2. Research Aim and Objectives

The main aim of my thesis is to inform the conservation planning of endangered species found in the complex socio-ecological landscapes of developing countries. I use a general framework of conservation planning to present my work and use the Irrawaddy dolphins, *Orcaella brevirostris,* in Chilika Lagoon, India as a case study. It is my thesis that the conservation of endangered species is a socio-ecological issue and that the interplay of politics and common property ownership greatly influences conservation outcomes.

The thesis has three main objectives:

Objective 1. To carry out a systematic assessment of the status of Irrawaddy dolphins in Chilika Lagoon, India, and to study the social landscape where conservation is to operate.

To address this objective, I amassed a large amount of social and biological data and used this information to assess the status of the population of dolphins in Chilika in the socio-ecological landscape in which conservation projects operate. I reviewed the social history of Chilika and the available literature regarding Irrawaddy dolphins to identify the gaps of knowledge for conservation practitioners. I estimated the abundance of Irrawaddy dolphins in Chilika Lagoon, the Extent of Occurrence and Area of Occupancy of the population, and the home ranges of individual dolphins. I use this population specific information for a regional assessment under the IUCN Red List Criteria. Chapters 2 to 9 of the thesis present this material.

Objective 2. To review current strategies to conserve dolphins in Chilika

Having determined the present status of the dolphin population in Chilika, and the threats it faces, the next step in my planning framework was to review current conservation strategies. To address this objective I explored the human dimension of dolphin conservation in Chilika Lagoon. I reviewed stakeholder perceptions towards conserving dolphins in Chilika and the role of government led conservation activities. I explored the limitations and opportunities for conservation in the context of the established dolphin-watching tourism industry in Chilika. I considered the roles of stakeholder perceptions and requirements in using tourism as an alternate livelihoods option to enable the conservation of dolphins. I have addressed these matters in Chapter 2, 4 and 10.

Objective 3. To offer an action-research model of management to implement and manage conservation strategies in Chilika

The management of conservation projects in highly human dominated landscapes requires a mixture of conservation strategies that are inclusive of stakeholder collaboration and deliberation. I discussed the current perceptions of the local communities towards dolphins, dolphin-based tourism and dolphin conservation in Chilika Lagoon to inform the management of prevalent strategies. I reviewed the current governance and management system in Chilika to show its role in conservation projects in Chilika in Chapter 11 and offer a process by which to measure outcomes.

1.3. Conservation Planning

Measuring the efficiency and the outcome of a conservation project (Pressey & Nicholls 1989) (Cowling et al. 2004) in relation to project goals is necessary for successful conservation. In a world where conservation is irrevocably linked to human systems and conservation success depends on change in conservation behavior, linear models that describe the conservation process as a series of continuous steps (Figure 1.1) fail to recognize the complex and heuristic nature of social change (Riley et al. 2002) necessary to achieve conservation outcomes.

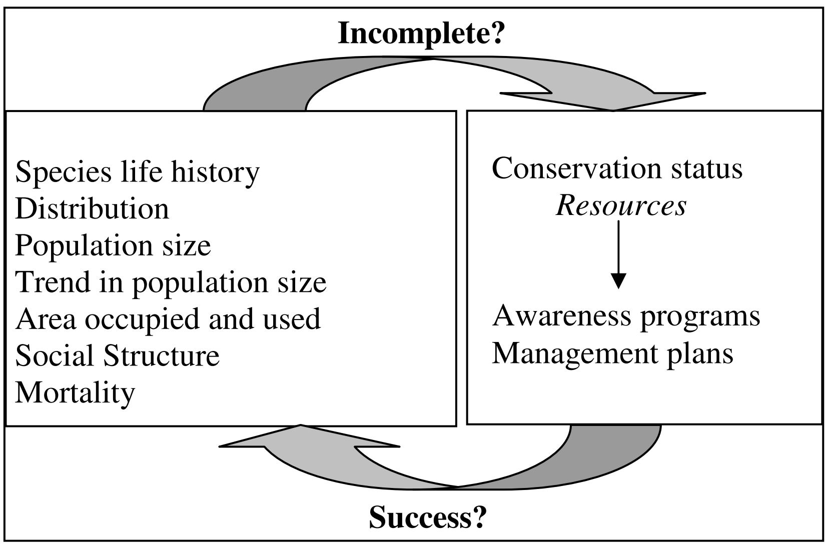


Figure 1.1. The conservation action model most commonly 'practised' in species conservation emphasizes systematic assessments of the biological entity to be conserved.

Conservation projects vary in scale from local efforts to protect a patch of forest or an endemic species to a global project to protect the oceans or migratory marine mammals. Various conservation planning frameworks, some of which include the human component of conservation, have been developed in the past decade and provide standard methods to design and assess conservation strategies in relation to defined conservation targets and goals (Pinkerton 1999; Margules & Pressey 2000; Groves et al. 2002; Riley et al. 2002; Salafsky et al. 2002; Sutherland et al. 2004; Knight et al. 2006; Nicholson et al. 2006). All these frameworks are designed for large spatial scales with the aim of biodiversity conservation. Nonetheless, the general frameworks (Knight et al. 2006) (Groves et al. 2002) can be applied for species and population level conservation.

The basic components of a general conservation planning framework (Knight et al. 2006) are: 1) systematic assessments of the conservation target and factors that influence its persistence, 2) designing appropriate strategies of action to mitigate the stress/disturbance/threats to conservation target, 3) implementing these strategies, and 4) measuring the success of strategies and revising them in an adaptive management cycle.

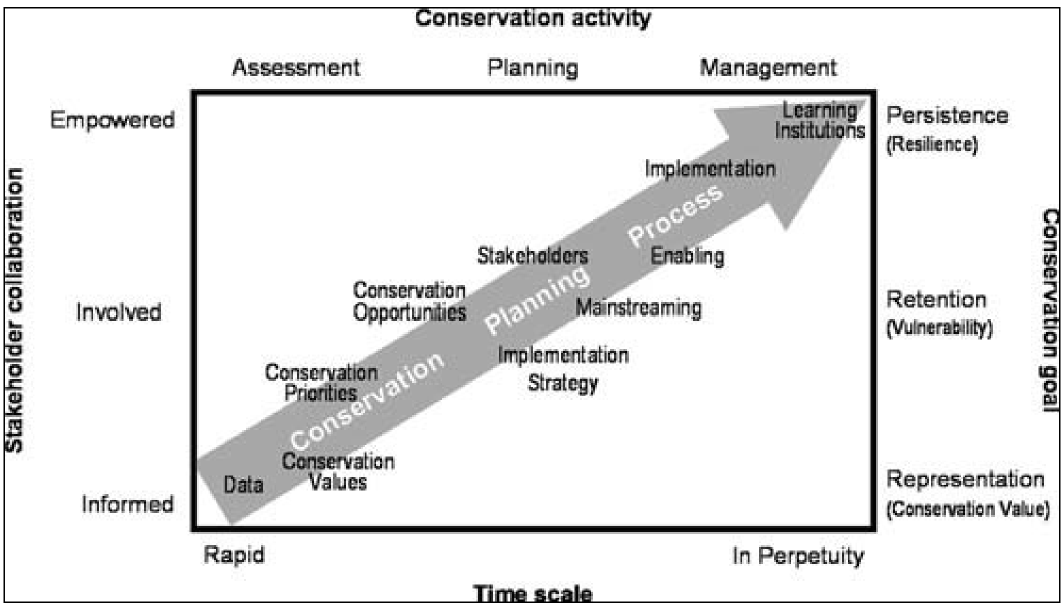


Figure 1.2. The process of conservation planning showing the interdependence of systematic assessments, planning and management with stakeholder collaboration and the outcomes over time in achieving conservation goals (Knight 2006)

Knight (2006) provides a model of effective conservation planning (Figure 1.2) showing the interdependence of all the components, in bringing about effective management and meeting conservation targets. The model shows that effective conservation practice is an action research process rather than a rapid and immediate conservation action. Action research is a reflective and interactive inquiry process led by individuals working in a team, that helps to progressively solve problems and to improve the way problems are addressed and solved. Problem solving actions are implemented collaboratively and are balanced with data-driven analysis or research to understand underlying causes that can predict and enable future social changes (Reason & Bradbury 2008). Action research is increasingly used in studying the human dimensions of wildlife management.

In recent years, there has been considerable development in the first component of conservation planning: systematic assessments. Systematic assessment models have been developed that accurately assess the extinction risk to conservation targets (IUCN 1994, 2003), classify threats of internal and external nature (Salafsky et al. 2008) and provide quantifiable targets of spatial risk to design conservation networks for mobile species and biodiversity conservation (Salafsky & Margoluis 1999; Margules & Pressey 2000; Sutherland et al. 2004). However the peer reviewed literature suggests that the success of most of these strategies has mostly not been evaluated. Most recent systematic assessments focus mainly on biological entities rather than the larger socio-ecological systems in which conservation planning operates. Assessing the role of stakeholder collaboration on implementation fills a gap between knowledge and action, and deals with the 'implementation crisis'. Systematic assessments of socio-ecological conditions that include biological entities, and the needs and perceptions of local stakeholders are ideally required to plan effective conservation projects. I documented the social perceptions of local communities and the solutions they suggested through my research.

The ecological data from systematic assessments for species conservation are very commonly used in linear models of conservation management, which depend only on the advise of 'professional experts' (Smith et al. 2007b). In the professional expert model, an expert is usually consulted to carry out a study to answer questions posed by decision makers or suggested by the researcher. The model thus provides empirical answers to the questions posed and advises decision makers regarding which course of action to take (Whyte 1989). But if a conservation project aims to bring about positive conservation behavior in a social system, expert opinion alone is not sufficient to generate knowledge or determine the course of social change. Measuring social change is not about making the right decisions. Rather, it is about setting up a social process that facilitates learning and trust between collaborators. If the professional expert behaves dominantly in setting decisions, local stakeholders and key individuals will not have a sense of ownership in the decision making process, but will rather feel subordinate thus hindering the learning and collaboration process.

Results from the systematic assessment are applied at the ‘Action and Implementation’ phase of the model. The action phase of the conservation planning framework includes deliberation with local stakeholders to exchange information and discuss problems. The deliberative phase is necessary to provide a common vision for the future. Reaching a consensus about the conservation goal and the strategies required to reach this goal should be an ongoing process in the ‘Action and Implementation’ phases of a conservation initiative. Actions should preferably include a range of strategies: enforcement of protection laws, awareness and education programs, and alternate livelihoods that link people to conservation targets (Salafsky et al. 2001). Finally, testing to assess if the actions and implementation of strategies bring about effective conservation is required to complete one round of action-research based conservation planning (Knight et al. 2006).

An operational model of conservation planning should communicate the steps of the planning framework to the stakeholders in the context of local social, economic and ecological conditions at the project site. In the next section, I review the components of the conservation planning framework in the context of Irrawaddy dolphins in Chilika Lagoon, India. Chapters 2 to 10 of my thesis provide data to inform these two components of the planning process. Chapter 11 offers an operational model to carry out conservation management and discusses the roles of governance structures, social systems and conservation practitioners in conservation planning.

1.3.1. Systematic Assessments of Status and Threats

Conservation projects that use a species or a population rather than a habitat or landscape as the conservation target have been source of much discussion (Brooks et al. 2004; Cowling et al. 2004). Systematic conservation planning of landscapes has the advantage of conserving a large number of ecosystems and hence multiple species (Margules & Pressey

2000) but often does not consider the ‘ground reality’ of socio-ecological conditions affecting implementation of such a plan. Considering the number of mammalian species listed as Threatened by the IUCN Red List 2008, the risk of losing isolated and fragmented populations, and the iconic value of flagship species the population of Irrawaddy dolphin, *Orcaella brevirostris,* in Chilika offered a valuable case study for conservation planning at the species level.

1.3.2. Conservation Action

Declining or small populations are generally considered prone to extinction and therefore of conservation interest. In most cases, the data required to assess their present status are unavailable, making future predictions uncertain. But to avoid such species becoming suddenly extinct, precautionary action as immediate intervention usually takes place, either through government institutions or by non-governmental organizations. In human-dominated regions, practice typically involves identifying the causes of threat, and mitigating these causes using incentives and awareness programs (Mascia et al. 2003).

The peer-reviewed literature documents threats facing marine mammal populations worldwide and the subsequent production of management plans for threatened populations. Case studies include populations facing threats from development activities (Jefferson et al. 2009), fishing gear entanglement (Perrin et al. 1994), vessel strikes (Van Waerebeek et al. 2007), vessel traffic (Bejder et al. 2006a) and direct human interactions (Samuels & Bejder 2004).

There are few examples showing the outcomes of the mitigatory measures to conserve cetaceans (Marsh et al 2003; Reynolds et al 2005; Jefferson et al. 2009; Jenkins et al. 2009). In Hong Kong, a range of very innovative mitigation measures has been designed and implemented to protect Indo-Pacific humpback dolphins and finless porpoises from industrial threats of large scale infrastructure development (Jefferson et al. 2009). Ongoing population monitoring surveys are being used to assess the success of these mitigatory measures; however, this approach only evaluates the ecological dimension of success and is thus limited in approach. In Swansea, Wales a local management plan to conserve a well studied population of harbour porpoises (*Phocoena phocoena*) was based on a dimensional analysis of threats, and the limits and opportunities of local governance and legislation on ongoing conservation activities. The management plan thus offers mitigatory measures, including changes in ongoing regulations and education programs (Jenkins et al. 2009) but does not include a process to measure the outcomes of the plan. In Cambodia, community-based tourism to promote community benefits from dolphin-watching was initiated at Kampi on the Mekong River (Beasley 2008) as an alternate livelihood strategy to enhance conservation outcomes. The project surveyed local perceptions towards dolphins and conservation to guide the development of the project. The success of the strategy to conserve dolphins and reduce the intensity of fishing nets in Kampi has not been evaluated (Beasley 2008). Similar situations are seen in a wide range of biodiversity and species conservation projects worldwide, wherein threats have been assessed and mitigatory measures offered and in many cases practiced, but the social and ecological outcomes of these measures have not been evaluated.

Incentive based programs like eco-tourism are increasingly introduced to a conservation area as a source of alternate livelihood. Interestingly, in Chilika, dolphin-watching tourism was developed by local stakeholders independently of any external conservation initiatives, but as an optional source of income. Dolphin-watching tourism has now become a major occupation which some see as an economic substitute to fishing. The opportunistic introduction of this alternative livelihood by local stakeholders is a major difference between the various conservation planning models proposed over the past decade (Salafsky et al. 2001). This situation allowed me to assess the prevalent social perception towards dolphins in the context of a developed tourism industry that acts as an alternate livelihood to fishing (Chapter 10 and 11). In the following sections, I explore in detail the strategy of alternate livelihoods as a source of conservation success.

Alternate Livelihoods

The social repercussions of the protected area paradigm brought the alternate livelihoods options to the forefront of conservation science (Salafsky & Wollenberg 2000; Adams et al.

2004; Adams & Hutton 2007). Various conservation programs have included people in conservation areas through the provisions of alternate livelihoods that decrease threats from human activities considered threatening to the ecosystem, like poaching and logging. It is assumed that if people benefit from alternate livelihoods or enterprises that depend directly or indirectly on a conservation target, they will take action to conserve and sustainably use the resource (Salafsky & Wollenberg 2000).

The Linkage Assessment Framework (Salafsky & Wollenberg 2000) provides a relative rank to the linkages between various alternate livelihoods and biodiversity across 39 projects conducted under the Biodiversity Conservation Network (BCN 1999). Livelihoods that utilize ecological services like eco-tourism produce the highest linkage rankings and therefore might be best suited for incentive based strategies (Salafsky et al. 2001). Salafsky (2001) tested the outcome of introduced enterprise or incentive based programs such as eco-tourism on biodiversity conservation outcomes. The results suggest that if the conservation linkage is not recognized by stakeholders, economic benefits do not necessarily lead to conservation success, but rather operate merely as an economic substitution strategy.

The Linkage Assessment Framework is thus a first step towards measuring the strength of linkages between various livelihoods and biodiversity at a relative scale of 1-5 (Table 1.1). The framework uses parameters similar to those of the IUCN Red List guidelines, but assesses the importance of a resource (in this case the Irrawaddy dolphin) to resource users (fishers or tourism operators in Chilika). One of the major limitations of using the Framework in my study is that it provides only an unweighted relative index of an activity's linkage with biodiversity/species. A more sophisticated scoring system would provide an index in which local stakeholders weighted the relative importance of the Framework components in Table 1.1.

I use the Linkage Assessment Framework in Chapter 11 at the species level and compare the linkage rankings from fishing and tourism for the Outer Channel of Chilika. To investigate the potential of the established enterprise as an opportunity for conservationists, I nest the Linkage Assessment Framework (Salafsky & Wollenberg 2000) (Salafsky et al. 2001) within the Action Phase of the conservation planning model. My results from Chapters 2 to 10 are used in this qualitative framework to assess the linkage between alternate livelihoods and Irrawaddy dolphins in the Outer Channel of Chilika Lagoon across five dimensions (Table 1.1)

1.3.3. Implementation and Management

In Chapter 11 of the thesis, I use the results from the systematic assessment of dolphins and social perceptions of local stakeholders to rank the linkage of tourism and fishing with conservation to propose an operational model of conservation planning in Chilika for Irrawaddy dolphins. The model is developed for use at the scale of local stakeholders. The model could be applied to any of the multiple strategies used to conserve dolphins in Chilika. As explained above, dolphin-watching was introduced by local communities in Chilika, independently of any conservation goals. I discuss the potential importance of information of local perceptions from stakeholders involved in the dolphin-watching industry as a sign of them recognizing and mitigating threats to their chosen source of livelihood, and a basis for future deliberations.

Understanding the prevalent conservation behavior (perceptions and preferences towards conservation) in local communities is a pre-requisite to conservation management, as the success and failure of strategies depends directly on this behavior (Ostrom 1990; Berkes & Folke 1998). Like any other form of social institution, conservation behavior is complex and influenced by cross-scale and cross-level relationships and agendas. Understanding conservation behavior requires a deep understanding of the complexities in multi-scale socio-ecological systems as I describe in Chapter 11.

Table 1.1. A framework to rank the relative linkage between livelihood and conservation target in the Outer channel of Chilika Lagoon

Five dimensions for ranking the strength of linkage between livelihood activity and conservation target	**Scores (one to five)**
Species dependence (will the livelihood activity be threatened if tourism target species decline?)	1. No species or just one species. 2. Two or three species. 3. A medium range of species present. 4. A wide range of species present. 5. The whole range of species present at the site.
Habitat dependence (is the conservation target found only in the Outer Channel and how will habitat quality in the Outer Channel affect livelihood?)	1. Always obtainable outside the natural habitat. 2. Usually obtainable outside the natural habitat. 3. Obtainable outside the natural habitat, but not at an economically competitive cost. 4. Technically obtainable outside of the natural habitat, but only with great difficulty and expense. 5. Not obtainable outside of the natural habitat.
Spatial dependence (is the livelihood activity prevalent in the entire area of the Outer Channel?)	1. Only one small section of the site < 5%.. 2. Several sections of the site (6-25%). 3. About one-quarter to three-quarters of the site (26-74%). 4. Most of the area of the site (75-95 %). 5. All of the area of the site (100%).
Temporal dependence (is the livelihood activity seasonal or throughout the year?)	1. Only a one-time use of the site. 2. Only occasional uses of the site for short periods of time. 3. Regular but not long-term uses of the site. 4. Repeated long-term uses of the site. 5. Continuous use of the site.
Conservation association (does the livelihood activity have conservation value i.e does it offer conservation benefits?)	1. Absolutely no green market potential. 2. Very limited green market potential 3. Some green market potential. 4. Substantial green market potential. 5. Extensive green market potential.

1.4. Thesis Outline

I have organized this thesis in 11 chapters, a format that is conducive to the flow of the conservation planning framework. Each chapter starts with a diagram showing the structure of the thesis and the specific objective being answered in that chapter. I have included tables and figures within the text of the thesis to maintain the flow of the text and highlight the results. The thesis ends with a list of References and Appendices. An overview of the thesis structure is outlined below:

Chapter 1 uses a conceptual framework of conservation planning to address Irrawaddy dolphin conservation in Chilika Lagoon, India

Chapter 2 reviews the current ecological information available for Irrawaddy dolphins from its range including Chilika Lagoon

Chapter 3 reviews the historical and prevalent socio-ecological condition of Chilika Lagoon

Chapter 4 provides an assessment of the well-being of stakeholders and their perceptions towards dolphins and natural resources in Chilika Lagoon

Chapter 5 assesses the isolation of the population of Irrawaddy dolphins in Chilika Lagoon

Chapter 6 estimates the abundance of Irrawaddy dolphins in Chilika Lagoon

Chapter 7 estimates the Utilization Distribution, space use and individual home ranges of Irrawaddy dolphins in Chilika Lagoon

Chapter 8 assesses site fidelity and social structure of Irrawaddy dolphins in Chilika Lagoon

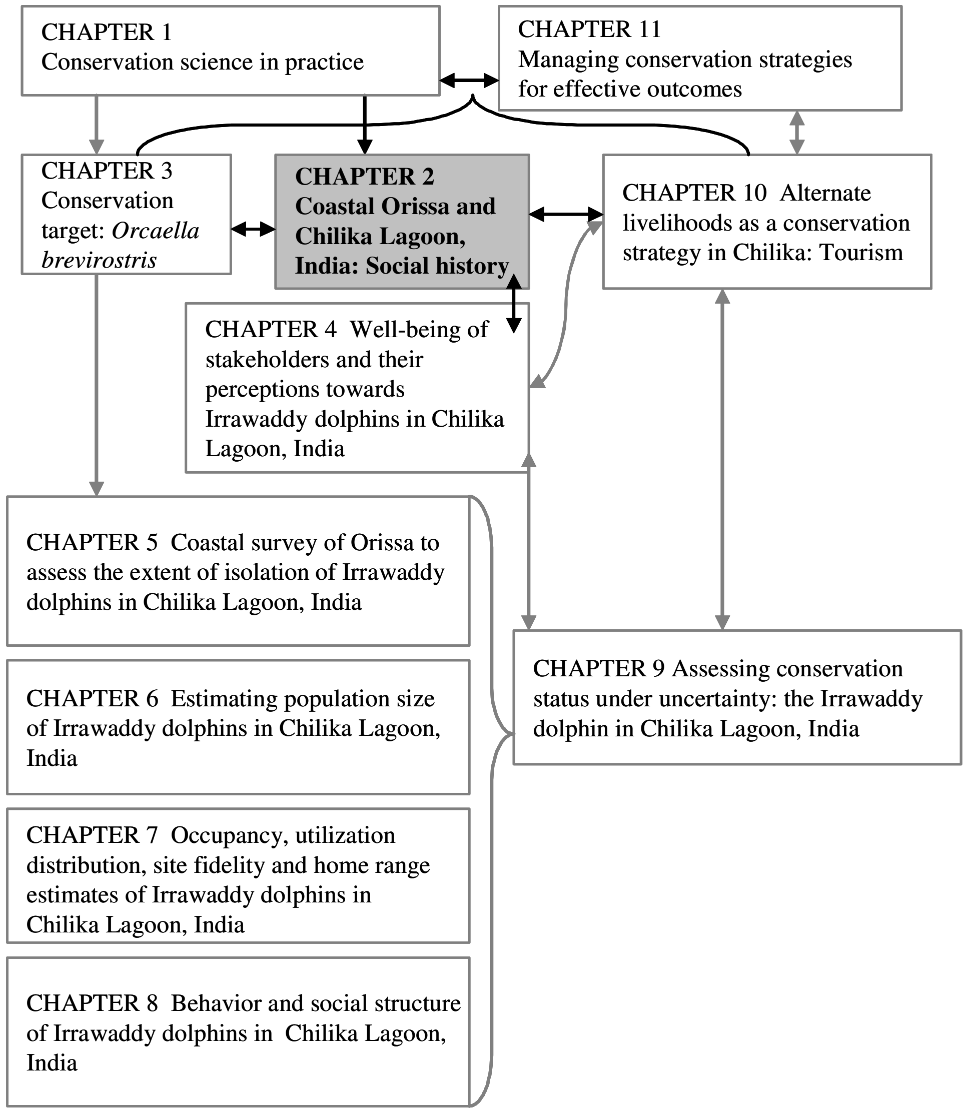
Chapter 9 assesses the conservation status of the Irrawaddy population in Chilika Lagoon using IUCN guidelines

Chapter 10 reviews the structure and functioning of the already established dolphin watching industry in Chilika

Chapter 11 discusses the current conservation actions, including the dolphin watching industry using the Linkage Assessment Framework. An operational model of action-research based conservation in Chilika is developed to represent the interplay between various social dimensions (scales and levels) that influences management in human dominated conservation projects.

References All the literature cited in the thesis are listed in a common reference list
Appendix A provides examples of photo-identified fins used for population estimation
Appendix B shows pictures of dolphins exhibiting feeding and socializing behaviors
Appendix C shows pictures of dolphins to differentiate between age classes
Appendix D shows available pictures of different fishing gears
Appendix E contains the home range maps for 34 individual Irrawaddy dolphins that were sighted more than nine times in Chilika Lagoon between November 2004 and April 2006 (Chapter 7).
Appendix F shows the different communication material created and distributed in Chilika during the study period.

2 THE COAST OF ORISSA AND CHILIKA LAGOON, INDIA



In Chapter 2, I review my study region in India at two geographic scales: 1) the regional scale, the coast of Orissa, in northeast India from where there are records of Irrawaddy dolphins, and 2) the local scale, Chilika Lagoon in south Orissa, which is home to a known population of Irrawaddy dolphins. The population of dolphins in Chilika lives under considerable pressure from the human population that also depends on the lagoon for resources. I therefore review the historical and current information on social and ecological conditions in Chilika Lagoon to set the landscape within which I will assess the status of the Irrawaddy population in Chilika.

2.1. Introduction

The state of Orissa is on the northeastern coast of India and is the western aspect of the northern Bay of Bengal. Chilika Lagoon is in the south of Orissa (Figure 2.1). The Bay of Bengal has lower and less stable surface salinity, and a lower biological productivity than the Arabian Sea on the western coast of India (Kumar et al. 2006). The influx of huge volumes of fresh water (1.5x1012 m^3 p.a.) and sediment (2000 million tons p.a.) from the Ganges-Brahmaputra deltaic basins and rivers into the Bay of Bengal (Rajawat et al. 2002) makes this Bay a depositional sink. The western aspect of the Bay of Bengal (or the east coast of India), is characterized by a narrow continental shelf followed by a steep slope (Pernetta 1993; Sarma et al. 2000; Kumar et al. 2006). Suspended sediment plumes formed by the deltaic river systems spread into the Bay in the north-south direction between 21°N and 17°N while ocean currents, sand movement and drift occur in the south-north direction (Rajawat et al. 2002; Madhupratap et al. 2003). As a result, the primary productivity in the Bay is highly dynamic, seasonally high only in near shore waters and unstable as a result of climatic events like cyclones. Marine mammal species tend to concentrate in areas of high prey availability. Below, I review the available information for the coast of Orissa and Chilika Lagoon, in terms of habitat types, quality and fish availability. This information is important to understand if Irrawaddy dolphins or other marine mammal could separate into preferred pockets of habitats, an important consideration while designing conservation strategies. I discuss the social conditions prevalent in Chilika, to assess the present and past socio-political pressures facing conservation practice at this locality.

2.2. Coast of Orissa

The coastline of Orissa is ~480km long and has a dynamic shoreline. Three seasons typically affect the oceanography of the coast: the North East monsoon (October to January), the South-West monsoon (June to September) and the fair weather period (February-May). Coastal topography is variable with 57% sandy beach, 33% mud flats and 10% marshy land (Ahmad 1972; Kumar et al. 2006).

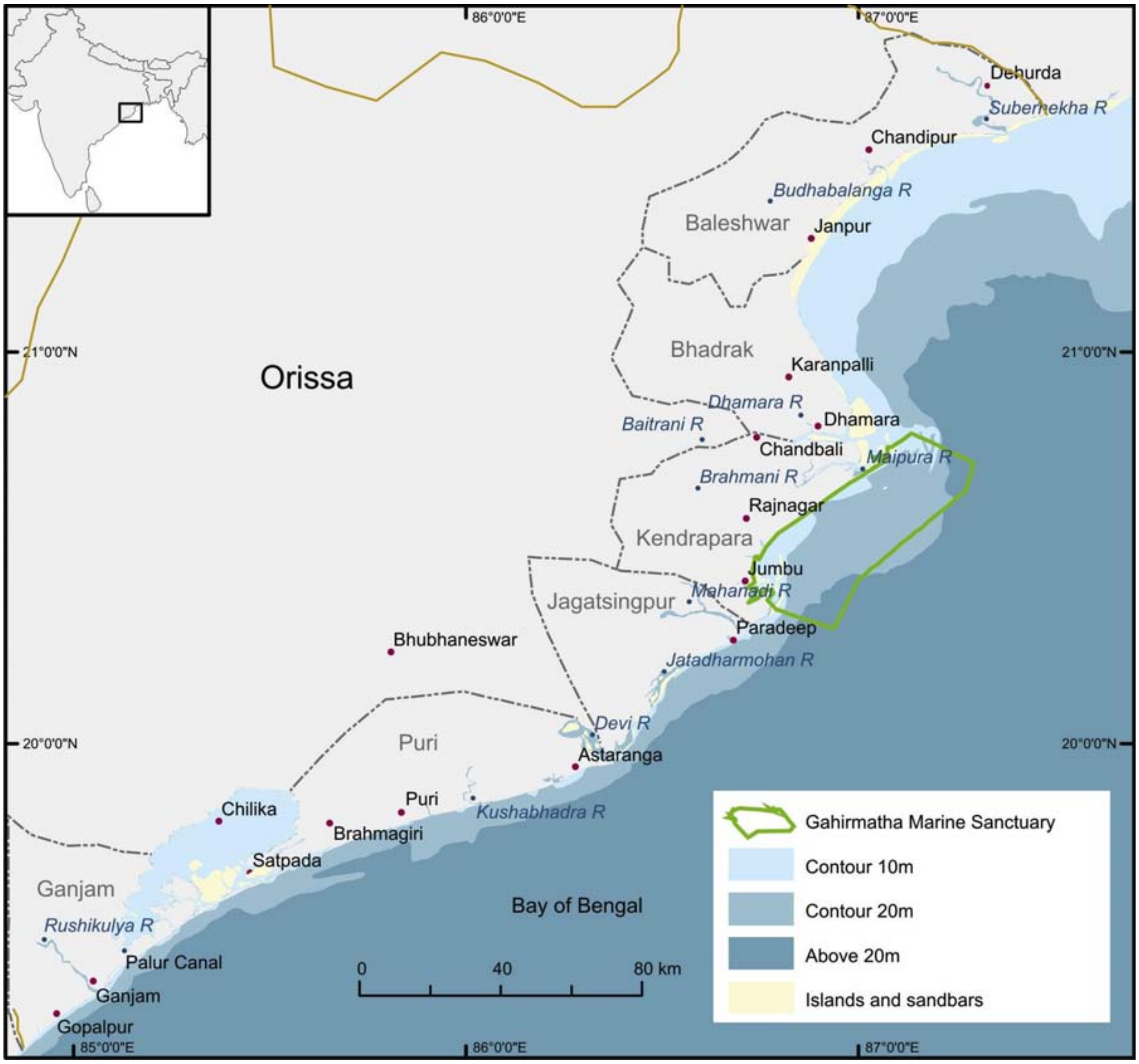


Figure 2.1. The coast of Orissa in northeast India showing the coastal districts, and important locations mentioned in the text with the range of coastal bathymetry.

The coast of Orissa can be broadly divided into two regions: (1) the coasts of Baleshwar (80 km), Bhadrak (50 km) and Kendrapara (68 km) districts in the north; and (2) the coast of Jagatsinghpur (67 km), Puri (155 km) and Ganjam (56 km) districts in the south. While the north Orissa coast is shallow, muddy and characterized by tidal flats and extensive river deltas, the south coast has sandy surf beaches (Ayyeppan & Jena 2000). The northern district of Baleshwar has the widest continental shelf (~41km wide at Janpur), narrowing southwards to ~20km at Dhamara,~10km at Paradeep, ~6km at Devi River mouth and ~4km at Gopalpur (Figure 2.1)

Seven main rivers originating from the Mahanadi River delta drain into the Bay of Bengal through Orissa (Figure 2.1). In the north and closer to the Sunderbans delta are the Budhabalanga (at Baleshwar) and Subernarekha Rivers (at Dehurda). Further south, the Brahmini –Baitrani system of the Mahanadi delta flows through the rich mangrove forests of Bhitarkanika Sanctuary and Gahirmatha Marine Sanctuary into the Bay of Bengal via the Dhamara and Maipura Rivers. At the mouth of the Dhamara and Maipura estuaries, there are offshore islands (group of Wheeler Islands), spits and sand bars. The coastal waters from Gahirmatha to the mouth of Chilika lagoon are rich in demersal and pelagic fish. The Mahanadi River (at Paradeep) is more centrally placed. In the south there are two main rivers- the Devi River (at Astarang) near Puri and the Rushikulya River (at Ganjam). Two branches from the Mahanadi system also empty vast amounts of fresh water and sediments into Chilika Lagoon. The waters from the Bahutia estuary at the southernmost tip of Orissa to the mouth of Chilika lagoon are the deepest near shore waters of Orissa and have a rocky bottom.

Orissa has a maritime coast with 589 marine fishing villages and 3678 villages involved in inland fisheries. Miscellaneous varieties of marine products contribute as much as 53% of the total production (Ayyeppan & Jena 2000). Marine catches are diverse comprising sciaenids (12.23%), followed by elasmobranchs (7%), catfish, hilsa, pomfrets, other clupeids, polynemids and prawns. The coast has one major shipping harbour (natural harbour) at Paradeep, four medium sized ports that also serve as fishing ports (Gopalpur, Dhamra, Chandipur, Nuagarh), eight major fishing jetties and at least 65 marine fish landing centres: 10 for motorized boats (motorized fishing gear as in trawlers) and the remainder for traditional motorized and non-motorized boats (DOF 1998). In 2004, permission was granted by the Ministry of Surface Transport to construct a ‘minor’ port at Dhamara, (Sekhsaria 2005). The construction of this port involved some 60 million cubic meters of dredging and maintenance over a 19 km long channel from the Dhamara port to the deep sea. The project covers an area of 1,000 acres for port construction and another 3,000 acres for other development activities related to port construction.

Dhamara Port and the permissions granted for its construction including a rather late Environmental Impact Assessment, have been a source of much contention and controversy as the Port lies along the northern boundary of the Gahirmatha Marine Sanctuary and Reserve

(Sekhsaria 2005; IUCN 2006b). The Gahirmatha Marine Protected Area and the Bhitarkanika Sanctuary along the coast of Orissa are rich in marine and mangrove biodiversity. The coast has not been surveyed for cetacean diversity, but anecdotal records suggest more than 12 cetacean species occur in coastal and offshore waters in this region (see Chapter 5). The coastal waters also harbor a very important breeding population of olive ridley turtles, *Lepidochelys olivacaea,* which congregate every year to lay eggs in arribaddas along several beaches along the coast of Orissa, particularly in Gahirmatha Marine Sanctuary. This site is globally important as a nesting site for the olive ridley turtles. With thousands of turtles killed each year in fishing nets (Pandav et al. 1997), the conservation initiative is a challenge. Community participation programs have been initiated to involve local stakeholders in olive ridley conservation as an acknowledgment of the livelihood value of biodiversity and community dependence on natural resources, (Shanker et al. 2005).The Orissa coast with its diversity of ecotypes, infrastructure, geomorphology and hydrology requires detailed and systematic assessments of changes in biological diversity in relation to environmental and anthropogenic influences. I assessed cetacean diversity along the coast of Orissa by carrying out a vessel-based survey (see Chapter 5).

2.3. Chilika

The formation of Chilika Lagoon is described in a mythological tale from the 4th century B.C: *"It is believed that King Raktabahu (Red Arm) had traveled across the seas in an armada to pillage the rich and holy town of Puri, north of Chilika* (Figure 2.1). *The citizens of Puri had deserted the town in anticipation of the attack which enraged King Raktabahu. He directed his fury towards the sea that had betrayed him. The sea in response, parted such that the entire army marched in before the waves turned in and drowned the entire army and its leader in its tides* [much like a Tsunami]. *The point where the sea parted is where Chilika was formed"*.

2.3.1. Ecology

Chilika Lagoon is a brackishwater lagoon located in Orissa, (19° 28'N - 19° 54'N and 85° 05'E – 85° 38'E; Figure 2.1). The lagoon is separated from the Bay of Bengal by a spit which is ~1.5km wide and 60km long. The lagoon is mostly enclosed, connected to the sea only by a single artificially dredged mouth (Figure 2.2). The Mahanadi River basin in north Chilika drains into the Lagoon throughout the year, where during the monsoon season more than 50 rivulets run into Chilika from its northern and western aspects.

The lagoon is oblong in shape, with a maximum length of ~64 km and an average mean width of ~12 km (Max=22km, min=200m) shrinking in size from ~1165km^2 in the wet season (June-September) to ~900km^2 in summer (March-May). The lagoon receives rain in December due to low pressure areas in the Bay of Bengal region. The lagoon is relatively shallow; depths are <6m even during the wet season. The salinity and pH in the lagoon vary depending on the region of the lagoon and the season and range between 0-45ppt and 7.0-10.9 pH respectively. Surface temperatures remain within 28°C-29°C (Ghosh et al. 2006).

The lagoon can be divided into four sectors- the Northern, Central, Southern Sectors and the Outer Channel to the sea. Most of the lagoon has a muddy substrate with the banks in the Southern and Central Sectors mostly weed-infested or unreachable due to the presence of fishing enclosures. The Outer Channel encompasses both sea grass beds with sandy substrate and muddy substrate with sea weeds.

The lagoon is a wetland of high social and ecological importance and is listed as a RAMSAR site. In September 2000, a 250m wide artificial mouth (Figure 2.3) was cut to the sea and a channel was dredged to connect the Outer Channel with the rest of the lagoon, to maintain the influx and circulation of salt water (Ghosh et al. 2006). The lagoon undergoes regular maintenance dredging to prevent silt collection in the northern and outer channels.

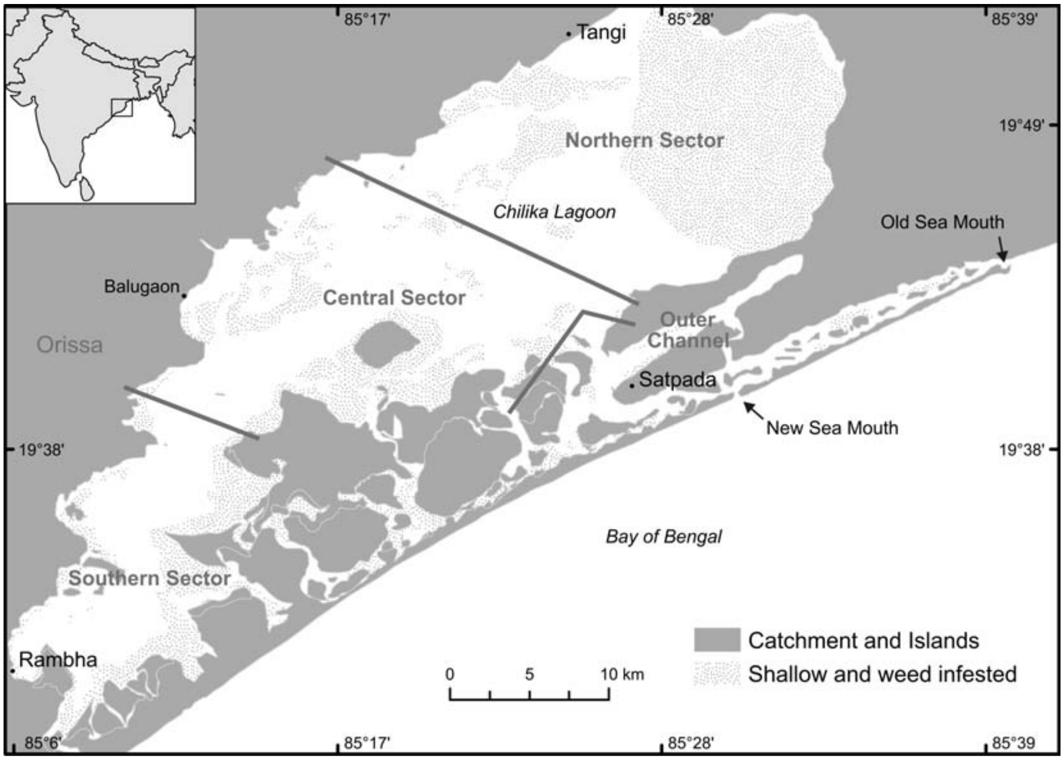


Figure 2.2. Chilika lagoon, Orissa India showing how the Lagoon was divided into different sectors for my study.

Figure 2.3. A view of the artificially dredged mouth to the sea in Chilika Lagoon, India.

2.3.2. Geological and Maritime History

Archeological explorations and excavations around the Chilika region show that several villages along the coast of Orissa and the present day west shores of Chilika participated in ancient maritime trade. In AD 150, Ptolemy referred to the *Palur port* south of Chilika, whereas in AD

638 the Chinese pilgrim Hiuen Tsang refered to *Chelitalo port*, but neither mentioned an enclosed Lake/Lagoon (Tripathi & Vora 2005) in relation to the ports. The earliest records of commercial fishing from Chilika are from 1592. This industry thrived till 1782 even though no human settlement was present in most of the Chilika region (Mughal era in Orissa was from 1592-1751; Maratha era in Orissa from 1751-1803) (Ray & Ray 2007). In the 19th century, Abdul Fazal described a port on the shores of Orissa that was located close to present day Satpada, confirming that Chilika remained a location of maritime importance through history.

2.3.3. Administrative Structure

Orissa was ruled by the Mughal Empire from 1592-1751 and then by the Marathas from 1751-1803. As stated above, Chilika has always been an important port and later a source of fish resources. With a history of changing kingdoms and governments, Chilika has been managed by various administrative structures. During the periods of Mughal and Maratha rule, Chilika was managed by village committees called *gram panchayats*, which were community based governing and operating bodies. Each panchayat leader reported directly to the King, also called the *Zagir* (based in Parikud and Khallikote), but the King did not play any direct role in managing fishery resources. In this system, *Zamindars,* or local Land Lords, kept records of catches and took some token fees for access to the resource, but the decisions of managing resources were all made by the *gram panchayats.* Later, even during the reign of the British Raj in the late 1800s, this *Zamindari System* prevailed under the Kings (Zagirs). Thus over generations, the fishers evolved a complex system of sharing and partitioning a common resource. Access was dependent on the type of fish harvested by any particular group or caste of fishers. Fishing was thus seen as an inherited right rather than a right of access from the government. The lagoon was officially divided into 333 management units from 1880, and fishing in a given unit was exclusively enjoyed only by communities that were fishers or individuals from a scheduled caste. Fishing was not considered an occupation suitable for upper castes.

A few years after the formation of India’s constitution (1950), Chilika was handed over to the State in 1953 as part of a centralized administration. At that time, the Orissa Department of

Revenue became directly involved in management of the lagoon resources. Various government administrative bodies are currently involved in the decision making process for Chilika. These departments are: 1) Orissa Department of Forest and Environment, 2) Orissa State Fisheries Department, 3) Orissa State Tourism Department, 4) Orissa Department of Revenue, 5) Orissa Department of Water and Irrigation and 6) The Chilika Development Authority. Orissa Department of Revenue has the highest stake in Chilika due to the export value of shrimp and fish from Chilika. A large number of policy decisions are thus largely dependent on the decisions of the district Collector (regional revenue assessor) who is based in Puri.

In 1992, Chilika Development Authority was created under the jurisdiction of the Ministry of Environment and Forests, as a coordinating body between institutions, industries and people who hold a stake in the lagoon and its basin. The institutional goal of the Chilika Development Authority is to decentralize the power systems that operate in Chilika. The Chief Executive of the Chilika Development Authority is directly advised by the Chief Minister of Orissa. The Chilika Development Authority governing body includes members of parliament and legislative assemblies, secretaries from the state and local administrative departments, technical experts and scientists who are all involved in the decision making process. Representatives of fisher communities are also members of the committee and are included in the decision making process (Kothari & Pathak 2006).

2.3.4. Demography and Economics

The different socioeconomic groups that depend directly on Chilika Lagoon for resources reside in more than 132 villages on the shores of the lagoon. Before the declaration of Indian Independence in 1947, people belonging to the upper castes did not carry out fishing. Today, these upper castes are involved in fishing but are termed ‘non-fishers’, thus dividing the people into two main groups: ‘fishers’ and ‘non-fishers’. Other occupations in the region are small businesses, teaching, and medical practice.

The lagoon is a major source of food and income for more than 132 hamlets with a varying number of households (50 to 350 houses) per village that reside along its shores. The subsistence economy is predominant with more than 30% of fishing villages actively involved in and dependent on fishing, aquaculture or fishery related business ventures.

With 30% of fishing village populations involved in active fishing (Sekhar 2004) there are around 12,363 fisher households and 150,000 fishers (Kadekodi 2000). The number of fishers has increased from 8,000 active fishers in 1957 to over 27,000 in 1996. The available census data suggest that the total fisher population is 122,339, of which 30% are male, 26% female and 44% children (Source: Directorate of Fisheries Statistics, 2000-2001).

The fishing population consists of sub-groups: Khatias, Keutas, Kandara, Niary, Tiaras, Kartias, Nolias and Bengali refugees. Each group uses different fishing gear and catches different species of fish. Only 43% of the population is literate, and dependency on fishing is inversely proportional to education level, since most educated people migrate to the cities and do not continue fishing (Kadekodi 2000).

A study conducted by the Nabakrushna Centre for Social Sciences sampled 30 villages (25 fisher and five non-fisher villages) covering 277 households in 2002. They estimated the average size of a non-fisher household to be 7-8 people and that of a fisher household to be 6-7 people. The annual per capita net income (PCNI) of the non-fisher households engaged in fishing or salt cultivation was estimated to be Rs 4,117 (100US$)[1] whereas that of the fishers was Rs 3,721 (90US$). The household net income was Rs 2,831 (5US$) for non-fishers if they were not engaged in fishing or salt cultivation. The annual income of the majority of the sample households ranged from Rs 2,000-Rs 4,000 PCNI (50-100US$). Both traditional fishers and aquaculturists tend to borrow money at high rate of interest from moneylenders, traders and agents (popularly known as commission agents, ‘chingudi’ agents) on the condition that they sell their whole catch at a predetermined price that is usually less than the prevailing market price.

[1] The exchange rate during my study period ranged from 1US$=43INR to 45INR based on data from www.xe.com/ucc/

2.3.5. Fishery – Past and Present

Before the British rule, traditional fisherfolk developed a complex system of rights and restrictions on fishing areas, seasons, techniques and gears. The arrangement resulted in sustainable fishing in the lagoon (Sekhar 2004; Ghosh et al. 2006; Sekhar 2007). Over time, however, the state intervened as Chilika was recognized as a source of income from shrimp culture, bringing in a range of external actors, ranging from local non- fishers to the State Revenue Department. The lagoon became a spatially managed and externally controlled unit for the first time in 1953. Open auctions were held to lease out the lagoon to fishers, (including for the first time leasing to non-fishers). The revenue was collected centrally. This step changed the face of the management regime from local and communal common property resource management to State owned and policed management. New methods of fishing were introduced including the use of nylon instead of yarn in traditional capture fishery (locally called 'Jano') and culture fisheries, including culture traps and ponds.

The lease system led to the formation of the Central Fisherman Marketing Co-operative Society (CFMCS) which sub-leased to the Primary Fishery Co-operative Societies (PMCSs) forming a hierarchy of institutions to manage the common resource. The lease policy changed over time leading to the large scale illegal subletting of fishing space. For the first time the Lease Policy of 1991, separated resources into 'Capture' and 'Culture' fisheries and also provided 'Culture' fishery rights to non-fishers. This policy became the root cause of conflict in Chilika. The district administration – revenue department in Puri allowed 30% of fishing grounds in Chilika to be changed into culture fisheries, causing an uprising from the traditional fishers. Conflict began with this basic change in policy, which entitled the non-fishers community to now use large areas of the lagoon for culture fishery. The conflict led the agitated fishers to form a union called the 'The Chilika Matsyajibi Mahasangh'. They demanded the abolition of all unauthorized shrimp culture within the lagoon. In response in 1996, the Supreme Court of India banned shrimp culture entirely in the lagoon and within 1000 m from the high waterline of Chilika. However, the State government could not effectively implement the court order. Two incidences of police shootings led to a loss of fishermen lives (the last one in May 1999) and caused the government to issue an executive instruction in 1999 banning the culture fishery from the lagoon. The union through local agitation has managed to thwart external interests like the one of the house of Tata

Industries in 1990s to start an aquaculture project. Today, 85 Primary Fishery Co-operative Societies (PCFS's) are active in Chilika although fights for the rights of the traditional fishers and to abolish aquaculture continue. The change in the fishing policy over the years is listed chronologically in Table 2.1.

The Supreme Court ban on 'culture' fisheries and the legitimate right of any non-fishers to carry out aquaculture in Chilika Lagoon has been a source of great conflict and discontent in a society dependent mainly on social bonds and bridges (Sekhar 2007). After the change in management regimes, the necessary social links between and across institutional scales of the human system were not built appropriately and even today are very weak. Even though the social bonds within fisher groups and bridges between communities are strong they have been strained over time due to the slow spread of conflict over aquaculture and non-fishers rights. In Chapter 4 of this thesis, I attempt to understand local fisher perceptions of their personal well-being in relation to the state of fish resources and management of Chilika, and the long term viability and conservation of natural resources in Chilika.

2.3.6. Tourism

Chilika is traditionally famous for the Ma Kalijai Temple in the Central Sector (Figure 2.2) of the lagoon and tourism in the South and Central Sectors mainly caters to cultural and religious tourists. During the months of November to January the South and Central Sectors also cater to tourists visiting the Nalabana Bird Sanctuary. A population of Irrawaddy dolphins, *Orcaella brevirostris* also resides in the Lagoon, and in 1989 a dolphin watching industry started in Satpada, in the Outer Channel of Chilika. Dolphin-based tourism in Satpada began with two boats taking out interested visitors to see dolphins, and currently consists of approximately 250 boats managed by the Dolphin Motor Boat Association-Satpada formed in 1991 (personal communication President of Boat Association 2004). Owing to disagreements within the executive committee, a new tourist association, Baba Chaubar Dev Motor Boat Association started in 2003 at Sipakuda, also in the Outer Channel of Chilika, which presently runs 87 boats. Both associations are operated by fishers who live near the Outer Channel and can easily switch to tourism. In Chapter 10 of this thesis, I explore the dolphin-based tourism industry in Chilika.

Table 2.1. Chilika Lease Policy from (Ray & Ray 2007)

Year and Policy	Type of Management and consequence
1880-1953	Lake divided in 333 Sairats under the British Land Settlement; fisher communities organized temporal and spatial limits and distributions to fishing amongst themselves. Zamindar leased out regions exlusively to fishers and the royalty was given to Raja of Purikud, Raja of Kalikote, Jagirdars.
1953-1959 Lease Policy	Zamindari system abolished; Fishery controlled by the Revenue Department of Orissa; Department via the *'Aanchal Adhikari'* auctioned most leases of fishery source to fishers and few to non-fishers
1959-1988 Lease Policy	Chilika Reorganisation Scheme formed the first Central Fishers Co-operative Marketing Society Ltd which leased fishery sources annually from the Revenue Department and then sub-leased to the Primary Fishers Co-operative Societies. Non-fishers were not given any special fishing rights. Primary Fishers Co-operative Societies often illegally subleased to private parties. Shrimp/Prawn culture started in 1980s
1988 Lease Policy	An amendment of the 1959 Scheme. Leasing time was increased from one year to three years, but no subletting to third parties was allowed
1991 Lease Policy	This Lease Policy divided the fishery into two types for the first time-Capture and Culture. It stated that all capture fishery sources may be leased out for three years to the Central Fishers Co-operative Marketing Society Ltd which can sublease to the Primary Fishers Co-operative Societies who may be given a viable culture source while the rest of the culture sources including landmass may be leased out to people from neighboring villages, even if they were non-fishers. No more subleasing to third parties was allowed. Thus, this lease policy for the first time allowed for the legal use of fishery resources, especially culture sources for both non-fishers and fishers in a 60:40 ratio respectively. While the right for non-fishers was not recognized as per cultural systems, the rights were granted for livelihood based on the state justice system.
1994 amendment	The 1991 lease was challenged by fishers asking for equality in distribution of culture and capture sources between fishers and non-fishers. A High Court ruling denied the challenge instead granting the non-fishers fishing rights. The amendment defined 'culture' and 'capture' sources, defined the size of area allocated for culture fishery and gave power to the Fishery Department. But most of the villages in the northwest of Chilika were not allocated any culture fishery which led to future conflict.
1996 Supreme Court judgment	Aquaculture was banned within 1000m of the lagoon by the Supreme Court leading to protests from non-fishers. From 1999, no further leases were given to either the Primary Fishers Co-operative Societies or to non-fishers. In 2001, the Government of Orissa completely banned shrimp aquaculture in the lagoon.
2002-2003	The Orissa Fishing in Chilika (Regulation) Bill 2002 was introduced banning all shrimp aquaculture in the lagoon. While the traditional fishers agreed with the bill, the non-fishers legislators challenged it. The amended Bill 2003 vested increased power in the Chilika Development Authority. The Central Fishers Co-operative Marketing Society Ltd was replaced by FISHFED who subleased to both the Primary Fishers Co-operative Societies and the Primary Non-Fishers Co-operative Societies, thus recognizing the non-fisher’s rights. Certain kinds of capture fisheries which are not traditional were allowed in the 2003 amendment, thus indirectly allowing culture fisheries in the lagoon. The power vested to the Chilika Development Authority is looked as a yet another threat to the original, local and communal system of managing resources. The current Fishing: Non-fishers lease has a 70:30 ratio

2.4. Discussion

Chilika Lagoon in southern Orissa is mostly enclosed apart from a single artificially dredged mouth to the sea via the outer channel. The lagoon is a RAMSAR site and known for an endangered population of Irrawaddy dolphins and for the migratory birds that visit the lagoon every year. Biodiversity conservation in the coastal waters has been challenging, leading to the recent developments in co-management and involvement of local fisher communities in Chilika Lagoon.

The social history of Chilika shows that there is a high degree of conflict amongst the local stakeholders regarding fishing rights and ownership in Chilika. The politicization of common property fishery resources has led to protests and bloodshed demonstrating the level of dissatisfaction towards present and past policies. Conflict has also grown in the recently developed tourism industry where competing tourist associations have been politicized.

This chapter illustrated the interplay of administrative, occupational and operational complications that can influence conservation initiatives and outcomes. Issues of power, vote banks[2] and profit influence politics at the administrative level. A more transparent system of discussion amongst government bodies maybe required for effective governance and to better facilitate communication between conflicting groups in Chilika. The inclusion of local stakeholders in key decisions would also be a step forward in resolving grassroots conflicts pertaining to fishing rights and tourism.

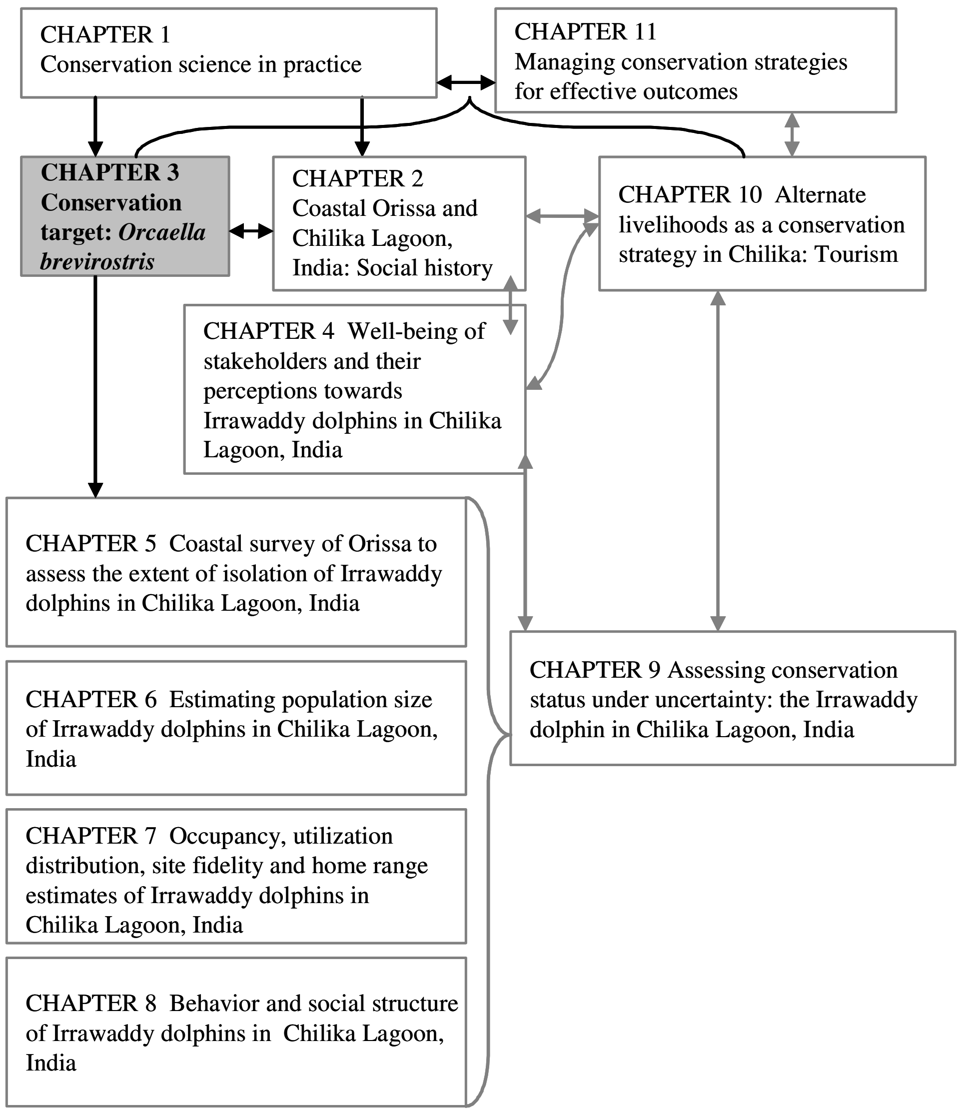
Due to the ongoing conflict between groups, communities in Chilika are wary of external interference or involvement in their affairs. To incorporate dolphin conservation and sustainable use of resources into the daily lives of the people could require designing strategies that consider the circumstance of the communities, their interrelationships between each other and with actors on other scales, and their perceptions. It would also require the full participation of the communities in designing these strategies.

[2] A vote-bank is a group of voters from a single community who consistently back a certain political party. It is usually created through divisive policies and encourages voters to vote on the basis of narrow communal considerations, often causing rifts even between neighboring communities.

2.5. Chapter Summary

- Productivity in the Bay of Bengal is high only along the coastal stretches. Thus the coastal ecosystem is used extensively by both fishers and aquatic animals.
- Orissa, a coastal state in northeast India has a highly dynamic coast with deep, rocky shores in the south and shallow muddy regions in the north.
- Chilika Lagoon in south Orissa is a highly productive lagoon in contrast to the outside coastal and oceanic waters, and is home to a population of Irrawaddy dolphins.
- The incorporation of dolphin conservation and sustainable use of resources into the daily lives of the people would require designing strategies that consider the circumstance of the communities and their interrelationships between each other and with actors on other scales.
- Annual incomes in village households are relatively low, and augmenting income via conservation driven initiatives could be a mutually beneficial strategy and could stump conservation.
- Due to the ongoing conflict between groups, communities in Chilika are wary of external interference or involvement in their affairs.
- In Chapters 4, 10 and 11, I offer some insight into the questions of perceptions of local communities, the scopes and limitations to conservation within a system vulnerable to conflict.

3 IRRAWADDY DOLPHINS *Orcaella brevirostris*



In this chapter, I begin to address objective 1, and introduce my study species and the sub-population of conservation interest. I review the current ecological information available for Irrawaddy dolphins throughout their range including Chilika lagoon. I focus on information originating in India where the type specimen was found. I show that Irrawaddy dolphins are generally found in small isolated populations, and that they are regarded as 'Data Deficient' (IUCN 2007) at the global scale. I summarize the information available for the sub-population in Chilika Lagoon, describe extant strategies to conserve this small population, and justify this population as an appropriate case for assessing conservation planning and success at the local level.

3.1. Introduction

Irrawaddy dolphins (*Orcaella brevirostris*) occur in the tropical and subtropical waters of the Indo-West Pacific region. The species is classified as a facultative river dolphin as a result of its ability to adapt to both freshwater and saline water environments (Smith & Jefferson 2002). Coastal and estuarine populations occur close to river mouths, and freshwater populations tend to stay within river systems and do not move into coastal areas (Stacey & Arnold 1999; Kreb et al. 2007). The Irrawaddy dolphin has a patchy distribution with geographically isolated populations in rivers, lakes or lagoons.

In this chapter, I review the ecological information available for the Irrawaddy dolphin throughout its range to provide a context for my study. I show that the population in Chilika is small, locally threatened, and with large gaps in the knowledge of its ecology. These characteristics make the conservation biology of the Irrawaddy dolphin in Chilika an excellent case study.

3.2. Review of Current Knowledge

3.2.1. Taxonomic History

The type skull of the Irrawaddy dolphin, *Orcaella brevirostris* Gray 1886, was first reported from the mouth of the Godavari River, Vishakhapatnam on the southeastern coast of India (Figure 3.1), by Sir Walter Elliott in 1852 (Owen 1866; De Silva 1987). The genus was originally considered to have two species *O. brevirostris* and *O. fluminalis* and later considered mono-specific and all the populations were recognized as a single species *O. brevirostris* (Rice 1998). Recent investigations by Beasley et al. (2005) reviewed the skull morphology of specimens throughout the range, showing that Australian populations of *Orcaella* are distinct from the Asian populations and thus taxonomically separate at species level (Beasley et al. 2002b; Beasley et al. 2005). Two species, *Orcaella brevirostris* and the newly described distinct species *Orcaella heinsohni*, the Australian snubfin dolphin were proposed (Beasley et al. 2005). *O. heinsohni* is now officially recognized by the IWC and the IUCN (Reeves 2008). The position of the genus is not yet resolved. *Orcaella* was previously considered to belong to the family Monodontidae (Barnes et al 1985), along with the beluga and narwhal, but recent cladistic analysis of osteological and morphological data and genetic analysis (Gretarsdottir & Ulfur 1992; Arnold & Heinsohn 1996) provide evidence that place *Orcaella* within the family Delphinidae. Genetic data also establish the killer whale, *Orcinus orca* as the closest relative to *Orcaella* (Arnold & Heinsohn 1996; Smith & Jefferson 2002). There have been no genetic studies to examine population structure and genetic inbreeding for any *Orcaella* population. Considering the general lack of information for the genus, I include information about *O. heinsohni* in the discussion below.

3.2.2. Global Range

The range of *Orcaella brevirostris* extends from the western Bay of Bengal, India possibly from Madras leading north along the coasts of Bangladesh, and southwards to Myanmar, Thailand, Cambodia, Vietnam, Philippines (Palawan), Malaysia, Brunei Darussalam, Singapore and Indonesia (Figure 2.1) (Stacey & Arnold 1999). Coastal populations of *O. brevirostris* are being studied along the coasts of Bangladesh and Myanmar (Smith et al. 2005), Gulf of Thailand (Hines et al. 2008) and Malampaya Sound in the Philippines (Dolar 1999; Bautista 2000; Buccat 2000; Smith et al. 2004). *O. heinsohni* is also being studied in Australia along the coasts of Queensland and the Northern Territory (Parra et al. 2006; Anonymous 2008) and in Western Australia (Thiele 2005). The Orcaella populations in Indonesia are probably O. *heinsohni*. Freshwater populations occur in three major river systems: the Mahakam (Kalimantan, Indonesia); Mekong (Laos, Cambodia, Vietnam); and Ayeyarwady (Myanmar) Rivers (Figure 3.1). These populations have attracted most of the research effort (Kreb 2000; Tun 2003; Beasley et al. 2007). Brackish water populations are found in Songkhla Lagoon (Thailand) and Chilika Lagoon (India) and both populations are currently being studied and monitored (Kittiwattanawong et al. 2007; Pattnaik et al. 2007).

3.2.3. Records from India

In India, the geographic range of *O. brevirostris* extends from the coastal waters off Visakhapatnam in southeastern India to the coastal waters of West Bengal (Figure 3.1) (James et al. 1989; Kumaran 2002). In 1977, a live animal was found stranded along the beach in Madras, Tamil Nadu (Miller 1997 ; Kumaran 2002; Sathasivam 2002), but there are no contemporary records to confirm the presence of the species along the southeast coast of India.

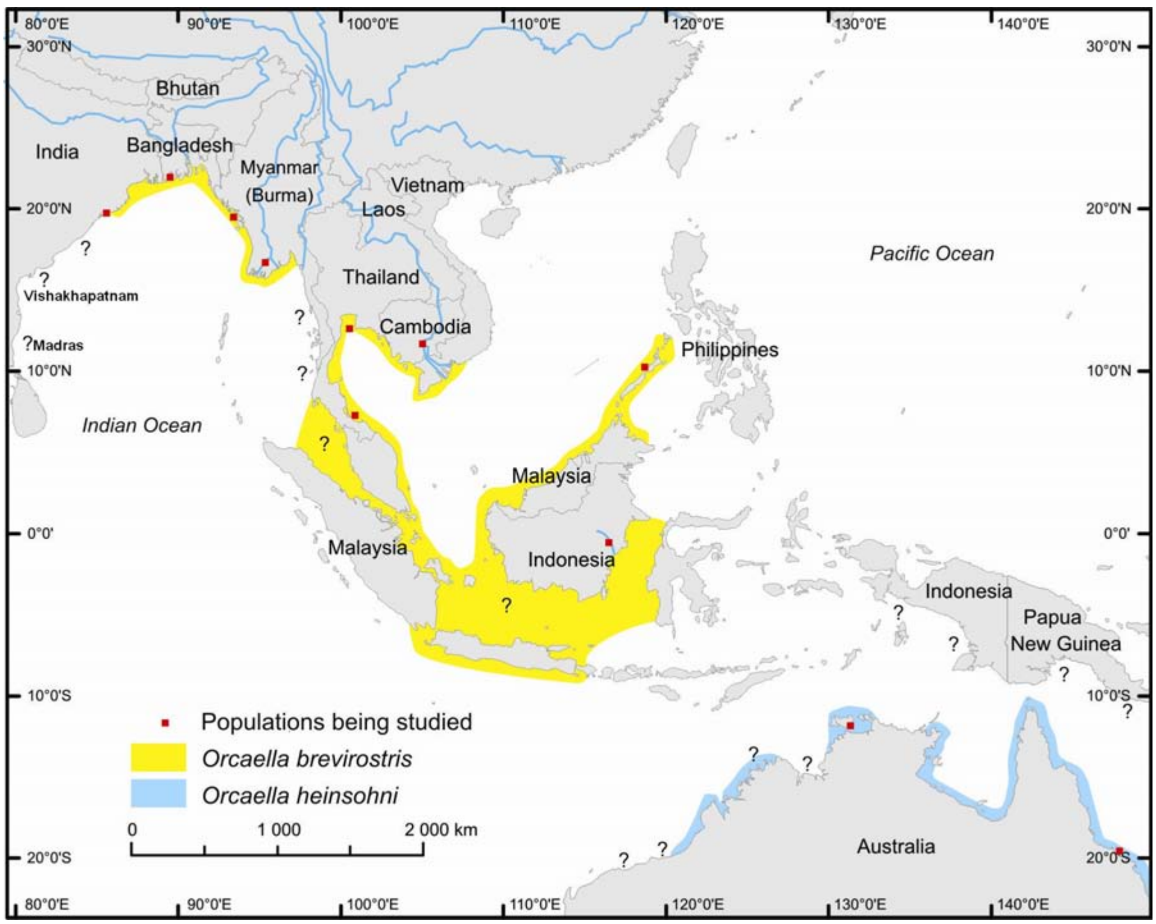


Figure 3.1. The range of *Orcaella brevirostris* (yellow) from India to Indonesia and the Philippines, and the range of *Orcaella heinsohni* (blue) in Northern Australia, showing the locations of populations currently being studied. Question marks show parts of the range of the species, where dolphins have not been reported recently.

Brackish water populations are found in the Sunderbans of West Bengal, India and in Chilika Lagoon, Orissa, regions separated by ~450km. The population in the Sunderbans of India has not yet been studied and reports exist only in grey literature and tourist photographs. The population in Chilika lagoon, India, was first recorded by Annandale in 1875 (Stacey & Leatherwood 1997) and has received attention in recent years. Forty years after he first recorded the population, Annandale confirmed the continued presence of the species in the lagoon (Annandale 1915). Outside Chilika lagoon, there has been only one other published record of an *O. brevirostris* carcass from Orissa - in the Gahirmatha region (Figure 2.1), approximately 250km north of Chilika (James et al. 1989). There have been no recent records of sightings or carcasses from the Gahirmatha region.

3.2.4. Abundance

The fundamental biological information on which to base conservation strategies for a population is to estimate population parameters in a way that can be repeated and tested. Estimating abundance is a challenge, often requiring the researcher to weigh the risk of biased estimates with resource capacity, logistics and weather conditions. The three main types of techniques used to estimate abundance of wildlife are Direct Counts, Distance Sampling using transect surveys, and Mark-Recapture Sampling using photo-identification. Most freshwater populations of cetaceans have been estimated using Direct Counts whereas Distance and Mark-Recapture Sampling have been more commonly used for coastal and oceanic populations (Hammond et al. 2002; Smith et al. 2006; Bradshaw et al. 2007) (Table 3.1).

The main drawback of the Direct Counts is that they do not provide measures of precision associated with sampling (Confidence Intervals and Standard Errors) to allow the investigator to test the power of the estimates or to model future trends. Concurrent counts analyzed within a Mark-Recapture framework are one way of converting count data to statistically testable data (Smith et al. 2006). But for elusive species like Irrawaddy dolphins, there is a high chance of missing animals disturbed by the research vessel or double counting animals due to 'flushing' making count based methodology challenging.

Distance sampling and Mark-Recapture methodologies, measure different parameters of abundance, but both provide statistical uncertainty around the estimates. Line transect sampling is conceptually a 'single survey' method that estimates the population that is in the survey region at that point of time. Mark-Recapture sampling is essentially a 'multiple-survey method' and estimates the size of the population that regularly uses the survey area. Thus, Mark-Recapture is highly appropriate in case of closed populations to estimate actual population size. Estimates from these methods can be used to model future trends. Few studies have compared results to show the strengths and weaknesses of the two methods (Jefferson 2000; Calambokidis & Barlow 2004; Gormley et al. 2005).

Strip and Line transect methods count the number of animals detected during a survey to estimate density, which is then extrapolated to an abundance estimate for the entire survey area. The Distance-based line transect technique estimates absolute abundance by modelling $f(x)$ (probability density function of distances) and the detection function $g(x)$, both depending on the 'perpendicular distance' to the cluster or object being counted. The two probabilities $f(x)$ and $g(x)$ are thus related by the effective strip width μ, $g(x)/f(x) = \mu$. The most critical assumption for the distance theory to work is $g(0)=1$ and in this case all animals close to the transect lines are detected, and the density function $f(0)=1/\mu$. If the assumption of $g(0)=1$ is violated, truncation can be used to model the data such that it possesses the property of $g(0)=1$. One rule of thumb is to use a strip width for which $g(\mu)= 0.15$. Subsequently the estimate of the density function $f(0)$ of detected objects is extrapolated to the entire region to correct for undetected objects resulting in a total abundance for the area. Truncation of data to remove outliers so that modeling detection function can be done with fewer parameters does not bias results, but grouping data to estimate $f(0)$ should be done with caution (Buckland et al. 2001) as this could lead to direct biases in population size. Distance sampling is most appropriate for regional surveys covering large areas rather than small areas (Borchers et al. 2002), because: a) the chances of double counting individuals of mobile species like dolphins in transect based methods are high if the population is small and found in enclosed areas, and, b) the chances of missing animals on the transect lines are high if animals get disturbed by research vessel, c) it is very difficult to obtain a large enough sample size if the population is small and distribution is clumped even if adaptive sampling is adopted. In fact, the assumption that $g(0) = 1$ is often false and new methods have been developed to avoid this assumption (Laake et al. 1997).

Mark-Recapture methods are most applicable to populations that are small and found in enclosed areas and where individuals can be 'marked' either naturally or by 'sampling'. Mark-Recapture methods require at least two sampling occasions, and require a substantial proportion (30%) of identifiable individuals to be marked. The method provides an estimate of the number of animals occupying the area over the period of study, sometimes extending over years, and thus can also provide survival rates, the most important life history parameter for long living slow breeding species such as cetaceans(Taylor et al. 2007a). Other potential uses of Mark-Recapture methods include mapping movements and analyzing social affiliations. The main challenge associated with using Mark-Recapture methods is to be able to account for and model sampling heterogeneity to produce precise population estimates. As seen in Table 3.1, Mark-Recapture methods provide more consistently precise estimates than Direct Count and Distance based methods for small populations of cetaceans for which its is possible to achieve a reasonable sampling fraction. Table 3.1 includes the various population estimates for Irrawaddy dolphins throughout their range to compare the precision obtained from different methods. Unfortunately, the methods used in different locations have not been standardized. This variation in methods makes direct comparisons impossible.

Abundance Estimates

Bangladesh Coast: In the inner Sunderbans, independent observers made concurrent counts and the data were analyzed within a Mark-Recapture framework using Closed Huggins models. A total of 451(CV=0.09) Irrawaddy dolphins were estimated to use the inner Sunderban riverways (Smith et al. 2006). Line transect surveys along the coast of

Bangladesh in the outer Sunderbans region (Smith et al. 2005) used diagonal transect lines across the depth gradient and covered a trackline variously represented as 1018km, 779km or 780km. Smith (2005) estimated an abundance of 5383 (CV=0.39) Irrawaddy dolphins for the survey region assuming that the detection probability g(0)=1 i.e, that all animals along the line were detected. They justified this assumption by their use of a dedicated observer to detect animals on the trackline. At an effective strip width of 292.2m, data were pooled into 100m bins for plotting the sighting distance histogram to model the probability density function f(0). Smith (2005) suggests that data heaping around the transect line in the sighting distance histogram confirms that g(0)=1. This crucial assumption is not necessarily true. Considering that the effective strip width was only 292.2 m, the 100m bins are probably too wide and could be a source of bias in the population estimate which may over-estimate the population size (Buckland et al. 2001).This bias will produce a higher value for f(x) than true, thus overestimating population size based on the general equation that D=n*f(0)*S/2L where n is the number of clusters/groups sighted per transect, S is the group size and L is the length of the particular transect. I conclude that despite the uncertainty in population estimate, the population of Irrawaddy dolphins along the coast of Bangladesh is substantial.

Myanmar Coast: The coast of Myanmar was surveyed using the method of Smith et al., (2005) and covered 955km of trackline, but only 12 individuals were sighted here (Smith et al. 2005). No abundance estimates are available.

Cleveland Bay, Australia: The Mark-Recapture method with Open Population models was used to estimate the population size of the Australian snubfin dolphin (*O. heinsohni*) in Cleveland Bay, Queensland-Australia between January 1999 and October 2002. An estimate of population of 76 animals (CV=0.08) was obtained with an average mark rate of 0.70 over the four years of survey (Parra et al. 2006). The population is not geographically or demographically closed. The area is used intermittently by the dolphins, making it difficult to obtain a discovery curve with a plateau. Where the animals go when they are not in the Bay is unknown. In such cases, it becomes necessary to be able to model immigration and emigration rates using open population models to estimate survival and population size.

Malampaya Sound: Dedicated cetacean surveys of Malampaya Sound have been conducted since 1999. The most recent estimate of the size of the population is 77 individuals (CV=0.27), based on Distance-based line transect sampling (Smith et al. 2004). Both the inner and outer Sound were surveyed covering 884km of trackline but Irrawaddy dolphins were sighted only in the shallow waters of the inner Sound. Only this inner sound region was used to estimate abundance in Distance.

Mekong River: The species has been recorded from the Mekong in Southern Laos, Cambodia and Vietnam (Baird & Mounsouphom 1997). In 1997, Direct Count methods gave a total estimate of 200 animals (Baird & Beasley 2005). More recent surveys estimated population size to be 68 (range: 54-88) using Direct Counts, 161 (CV=0.30) using Distance sampling and 127 (CV=0.07) using Closed Mark-Recapture models (Beasley et al. 2007).

Mahakam River: In the Mahakam River of Kalimantan, Indonesia, Irrawaddy dolphins are found up to 690km upstream. Strip-transect analysis and Direct Counts made during nine surveys conducted between early 1999 and mid 2001 within the entire range of dolphin distribution estimated 37 (34-40) and 33 (32-36) individuals, respectively (Kreb 2002; Kreb et al. 2007). A Mark-Recapture analysis using open population models of surveys conducted from 1999-2002 indicated a slightly larger population size of 55 (CV=6%) and 48 (CV=15%) individuals (Kreb 2002; Kreb et al. 2007). Based on Mark-Recapture surveys in 2005 and Open Population models, the population size was estimated to be 70 individuals (CV=10%; 95% CL = 58-79) (Kreb 2002; Kreb et al. 2007). Direct Counts based on total number of identified dolphins in 2005 estimated the population at 67 individuals. Kreb et al.(2007), claimed that the higher 2005 estimates do not indicate population growth but are the result of higher capture rate in 2005 of 90% per sighting, compared with 63% per sighting in 1999 – 2002. They attributed the difference to the use of digital photography starting in 2005. Earlier Direct Count and

Strip-transect estimates were most likely underestimates due to sighting biases (Kreb 2002; Kreb et al. 2007). All the estimates indicate that this population is very small.

Ayeyarwady River: Irrawaddy dolphins were first recorded in the Ayeyarwady River of Myanmar 1871 (Anderson 1879) and recently have been recorded along the entire navigable length of the river (Tun 2003). Recent research using Direct Counts has estimated 33-76 individuals in the River (Tun 2003; Smith & Tun 2007a). The population continues to be monitored using Direct Count methods as individuals do not have natural marks useful to delineate individuals.

Songkhla Lagoon: Dolphins have been recorded from Thailand since the early 1900s, but were studied in Songkhla only in 1974 (Pilleri & Gihr 1974). Surveys have been undertaken in Songkhla using standard monitoring techniques and the most recent estimate is that there are fewer than 20 animals in the entire lake (Beasley et al. 2002a; Kittiwattanawong et al. 2007).

Chilika Lagoon: Annandale (1915) reported that the population was numerous without providing any quantitative estimate. Much later, in 1997 (Dhandapani 1997) the population was suggested to be very small - about 20 individuals. In 2004, a study suggested that the population could number as few as 50 individuals (Sinha 2004). Starting in August 2002, the Chilika Development Authority began a comprehensive study of the status of the population. In 2007, they estimated the population size to be 135 dolphins using synoptic Direct Counts and, 138 animals in 2008 using the same method (Pattnaik et al. 2007). This method counts the dolphins from 18 boats starting at different parts of the lagoon at the same time on the same day. This approach could lead to missing animals that remain underwater or double counting due a 'flushing effect' on animals. The method does not provide any measures of uncertainty to allow the assessment of the power to detect trends in population size over time.

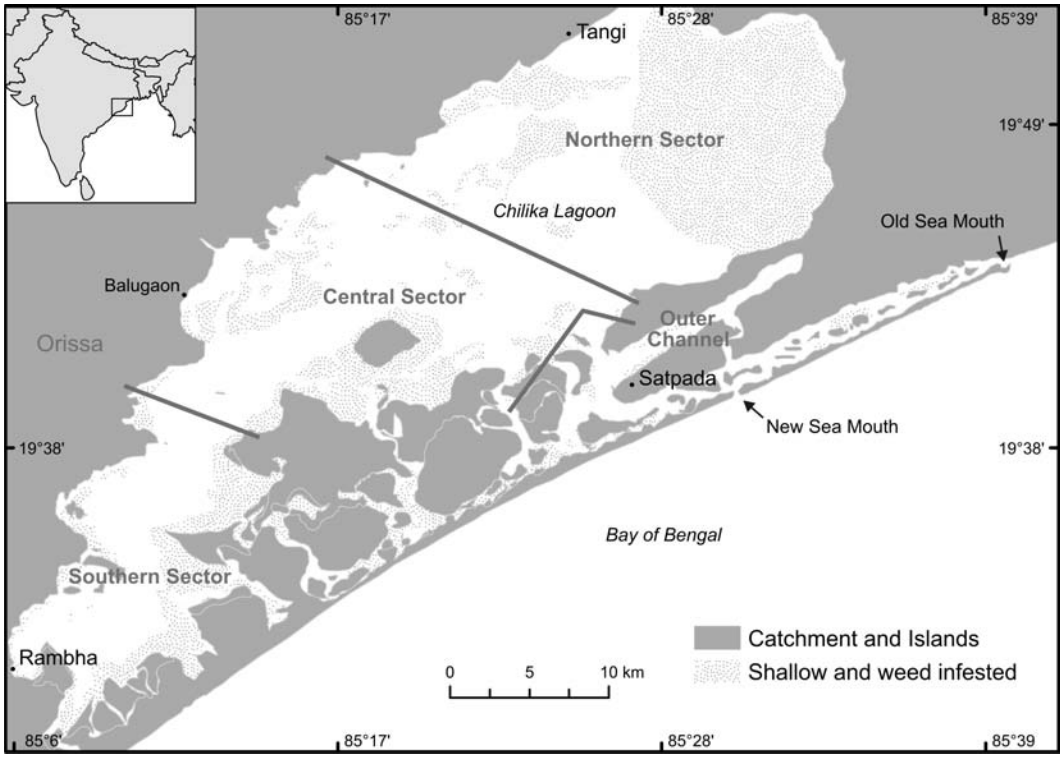


Figure 3.2. Chilika Lagoon in Orissa, India showing the four sectors of the lagoon, weed infested area and location of the new and old mouths to the sea.

Table 3.1. A comparison of the precision obtained from estimates of the size of small populations (< 500) of *Orcaella sp* monitored using various sampling techniques

Species	Population	Habitat	Survey method and Year	Abundance	Estimate of Precision	Reference
O. brevirostris	Mekong River, Cambodia	Freshwater	Direct Counts (1997) Direct Counts (2001-2005) Line transects (2001-2005) Mark-Recapture (2001-2005)	40 sighted(200 estimated) 54-88 161 127	 CV=0.30 CV=0.07	Baird and Beasley 2005 Beasley 2007 Beasley 2007 Beasley 2007
	Ayeyarwady River, Myanmar	Freshwater	Direct Counts (2003-2004)	59-72		Smith et al. 2007
	Mahakam River, Indonesia	Freshwater	Direct Counts (1999-2000) Mark-Recapture (2001) Mark-Recapture (2005)	34 48-55 70	 CV=0.06-0.15 CV=0.1	Kreb 2002 Kreb 2007 Kreb 2007
	Chilika Lagoon(lake), India	Brackish	Direct Counts- *average of monthly counts (2002-2005)* *Annual instantaneous counts* *2006* *2007* *2008* *2009* Mark-Recapture (2004-2006)	 85 (SD=18.5; 62-98) 131 135 138 145 104-112	 CV=0.07	 Pattnaik 2007 CDA 2007 CDA 2007 IANS 2008 IANS 2009 This study
	Songkhla Lagoon, Thailand	Brackish	Opportunistic (1990's) Line Transects (2000) Aerial Survey (2004)	100 20 20		Anderson et al. 1994 Beasley et al. 2002 Kittawattanawong 2006
	Sunderbans, Bangladesh	Brackish	Direct Counts with Mark-Recapture 2002-2003	397-451	CV=0.10-0.09	Smith et al. 2006
	Malampaya Sound, Philippines	Brackish	Direct Counts Line Transects (2001)	7.4/100km 77	 CV=0.27	Dolar 2002 Smith et al. 2004
	Gulf of Thailand, Thailand	Coastal	Line Transects (2008)	1421	CV=0.53	Hines et al. 2008
	Bangladesh	Coastal	Line Transects (2008)	5383	CV=0.39	Smith et al. 2007
O. heinsohni	Cleveland Bay, Australia	Coastal	Mark-Recapture (2001-2005)	78-62	CV=0.09-0.13	Parra 2005

3.2.5. Life History

Life history information is very important for assessing the status and quantifying the viability of a population, but there is little or no information regarding maximum age, age of sexual maturity, generation lengths, calving rates, mortality rates, sex ratios, and growth patterns for Irrawaddy dolphins or Australian snubfin dolphins. The upward or downward trend in population size is a significant component of estimating the conservation status based on the IUCN Criteria (Kindvall & Gardenfors 2003; IUCN 2006a) but the lack of life history information makes it impossible to estimate actual population viability. Moreover, changes in population size in cetaceans are typically slow and obtaining precise estimates of absolute abundance or robust and precise indices of relative abundance is difficult as discussed in the previous section. Here, I review some of the information available on life history, and discuss the information required to make Irrawaddy dolphin assessments more robust.

If the life history of *Orcaella* conforms to the general pattern of cetacean life histories (Chivers 2002), Irrawaddy dolphins are likely to exhibit a minimum of 10 month gestation period, calving intervals of two to four years, late onset of sexual maturity and a lactation period of one to two years. Studies of one Australian snubfin dolphin in captivity (Stacey & Arnold 1999) in Queensland, Australia estimated the gestation period to be approximately 14 months, size of calves as 85-105cm, length at sexual maturity as 210-175cm, age at full body size as 4-6 years and a total life span of 30 years (Marsh et al. 1989). Nursing took place within 12 hours of birth and weaning by two years of age (Marsh et al. 1989).

Based on information from other small odontocetes, the age at first reproduction for Irrawaddy dolphins can be assumed to be 7-10 years of age and the generation time (average age of reproducing cohort) around 13-15 years (Taylor et al. 2007a). Recently, Kreb (2004) estimated calving and mortality rates for Irrawaddy dolphins in the Mahakam River to be similar at 13.6% and 11.4% respectively. Beasley (2008) also reported rather high mortality rates (~8 %) of which 43% were newborn calves suggesting a high calving rate for the Mekong population with a preliminary description of sex ratio distribution in the population to be 1:1. Beasley (2008) reported information including body size, age at first reproduction, size of oldest reproducing female and maximum female length, similar to earlier data for the snubfin dolphin (Beasley 2008). Despite ongoing research projects in various populations, not enough information has been collected to estimate sex ratios, maximum age/size, age/size at first reproduction, and calving rates of Irrawaddy dolphins, all of which play a very important role in modeling population viability and assessing the effect of threats on the population. This lack is a serious deficiency in the conservation biology of Irrawaddy dolphins.

3.2.6. Habitat Use

The IUCN listed 201 species of wildlife in India as Endangered in 2007 and for most of these species, habitat loss and fragmentation top the list of major threats (IUCN 2007). Habitat loss and fragmentation can lead to large scale loss of species for two reasons: a) the smaller a habitat becomes, the higher the risk of wildlife-human encounters and conflicts; b) decreasing habitat size and quality increase the pressure on the carrying capacity of the habitat. Understanding how a species uses its habitat and the natural and anthropogenic factors that can change the habitat, will help better manage the population. As stated earlier, Irrawaddy dolphins are found mainly in human dominated systems, in freshwater, estuarine and brackish water, and coastal systems. Within each of these systems, the species shows further specializations in habitat use and preference.

Coastal populations of Irrawaddy dolphins remain close to land throughout their range showing a preference for waters less than 20m deep close to freshwater sources and mangrove forests. Coastal Irrawaddy dolphins in Bangladesh and Myanmar have been found at an average depth of 7.5m and 18.8m respectively, at distances of up to 40km from shore (Smith et al. 2005). In some rare cases the Australian snubfin dolphin has, been found in deeper water at 30m and 23km from shore (Marsh et al. 1989; Parra et al. 2002; Parra 2006) .

Riverine and lagoonal populations of Irrawaddy dolphins apparently do not venture into coastal waters (Beasley et al. 2007; Kreb et al. 2007). In Songhkla Lagoon, all the sightings have been from only the relatively deep sections of the lagoon at a depth of 2-4m. Chilika is ≤5m deep for most of the year (Oct-June), increasing up to 6-7m during and just after the wet season (July-

September). Just outside Chilika Lagoon, the continental shelf is very narrow and the water drops to >20m deep beyond the shelf. Unlike coastal and lagoonal populations, riverine populations prefer deep water pools rather than shallow areas (Smith & Hobbs 2002; Smith et al. 2006; Beasley 2008). In the Ayeyarwady River (Smith & Hobbs 2002), dolphins were found in water up to 110m deep, whereas in the Mekong River animals mainly used waters at least 40m deep (Beasley 2008). The freshwater populations also show preference for confluences of rivers, calm slow moving waters and regions where fishing intensity tends to be high (Smith & Hobbs 2002; Smith et al. 2006; Beasley 2008). As explained below, in the Mekong, animals migrate during seasonal floods to remain within their preferred depth range and/or follow fish migrations.

3.2.7. Movements and Home Range

Understanding the relationship between animals and their environment – how much habitat they use and in what ways, will better inform the concept of conserving habitats to protect species in the long term. Very few studies have provided information on any long distance movements of Irrawaddy dolphins and the significance of such movements if they occur is unknown. Beasley (2008) reported a rescued dolphin released in Phnom Penh, traveling a linear distance of 294km upstream to a pool in which it resided for the next four years. Other reports from the Mekong show that individuals move a distance of 25-30km to deeper pools during the dry season and their home ranges vary from 11km^2 to 40km^2 (Beasley 2008). The only other report of large scale movements of greater than 35-40km (mostly during the flood season) was inferred from interviews in the Ayeyarwady River region (Smith & Hobbs 1997; Smith & Tun 2007a).

Individual Australian snubfin dolphins, were observed to have home ranges between 4-108km^2 in area, and the maximum distance individuals were observed to travel between locations was 4-33km (Parra 2006). Australian snubfin dolphins also show a pattern of lagged residence with temporal differences in habitat use, with individuals using a particular bay for around a month and then returning after a month or so away, to use it again (Parra et al. 2006).

3.2.8. Social Structure

Only Beasley (2008) and Kreb (2004) have analyzed the social structure of Irrawaddy dolphins. Both studies found that Irrawaddy dolphin society was highly structured, with a high degree of companionship between some individuals over time. Beasley (2008) found that the population formed four communities and that two of these communities interacted with each other while the other two remained isolated with no apparent association with other communities. Parra (2005) found that Australian snubfin dolphins generally occur in schools of fewer than 10 animals, with larger sized groups associated with socializing behavior. The dolphins also showed stable long term associations (Parra 2005). Parra found that the mean number of associates for the species was eight, of which four were casual and four were constant companions (Parra 2005). Taken together, these data indicate that the genus shows strong social stability and does not follow the Fission-Fusion model of social structure as seen in some other cetaceans e.g. *Tursiops sp.* (Connor 2000; Gero et al. 2006) where animals move among groups and associates are not always constant.

3.3. Conservation Status

As stated in the preceding section, a great deal of the information generally required for a science-based conservation assessment is lacking for Irrawaddy dolphins. The species was therefore assessed as 'Data Deficient' at a global scale in 1996 by the IUCN. Subpopulations in the Mahakam River (IUCN Red List 2000), and more recently, the Mekong River (IUCN Red List 2004), the Ayeyarwady River (IUCN Red List 2004), Songhkhla Lake (IUCN Red List 2004) and Malampaya Sound (IUCN Red List 2004) are now officially listed as Critically Endangered.

The population of Irrawaddy dolphins in Chilika has not been assessed by the IUCN Red Listing process. The Conservation Assessment and Management Plan workshop for Indian Mammals in 1997 (Molur et al. 1998) followed the IUCN guidelines and assessed Irrawaddy dolphins in India as Endangered under criterion B (EN B1, 2c). Criterion B is based on 'Geographic range where either B1 Extent of Occurrence $<5000km^2$ OR B2 Area of Occupancy $<500km^2$. In addition, two of the three sub criteria (IUCN 2006a) need to be true for the population to be listed as

Endangered. It is unclear why the assessors included sub-criterion ‘2c’. Formal documentation of the rationale is not available for the 1997 assessment, follow up assessments have not been carried out, and the assessment at the time was not proposed to the IUCN for listing as 'Endangered'. In Chapter 9, I assess the conservation status of the population of Irrawaddy dolphins in Chilika Lagoon using the IUCN guidelines at the regional scale.

3.4. Conservation Threats and Mitigation in Chilika

Annual dolphin mortality in Chilika (adults and calves) has been estimated as 7-8% (Pattnaik et al. 2007) (Table 3.2) based on figures from 2003-2006 (Pattnaik et al. 2007). Records suggest that annual mortalities have fallen from 15 (2003), 9 (2004), and 12 (2005) to 3 (2006), 5 (2007) and 5 (2008). Sixty percent of the carcasses are found around the Outer Channel of the lagoon (Figure 3.1). The dolphins face a range of threats, some of which are listed below, with the primary cause of death attributed to fishing gear including entanglements in nets.

Table 3.2. The distribution of carcasses from Chilika Lagoon recorded between 2003 and 2008 (Source of information: Orissa State Forest Department and Chilika Development Authority) – see Appendix C for age classification.

	Carcasses	Adult	Sub-Adult	Calf
Outer Channel	30 + 2 skulls	23	2	5
Central + South	16 + 1 skull	10	1	5
North	3	3		

3.4.1. Habitat Degradation

Chilika Lagoon is a highly dynamic system which has been undergoing continuous change. The details of its formation probably during the most recent sea level rise are detailed in Chapter 2. The Irrawaddy dolphins living in Chilika lagoon are vulnerable to both natural and human-caused changes in the lagoon. One of the major alterations of the lagoon started in the early 1980s with increased siltation from rivers which led to a choking of the mouth to the sea and subsequent shrinkage of the lagoon. The silt was not naturally flowing into the sea due to obstructions from large scale aquaculture that had clogged natural channels, slowing down the movement of silt (see position of old sea mouth in Figure 3.2). These factors along with the constant accretion of the shoreline, are continued causes of concern for habitat quality in the lagoon. As discussed in Chapter 2, a mouth was dredged to the sea in 2001 to prevent the lagoon from shrinking further and turning into marshland.

3.4.2. Over-Fishing

Chilika is a highly productive lagoon supporting 132 fishing villages and 200,000 people. The fisheries in Chilika compete with illegal aquaculture (see Chapter 2) which reduces natural seed stock. Aquaculture enclosures have taken over large areas of habitat important for juvenile fish and dolphins. More details about prevalent and historical social and economic conditions are given in Chapter 2. A large range of nets and other gear, both traditional and mechanical, are used and fish catches have declined over the last three decades. The fishery activities in the lagoon are regulated by the *Orissa Marine Fisheries Regulation Act of 1982* and *Orissa Marine Fisheries Rules of 1983* administered by the Department of Fisheries. The operation of large mesh gill nets, shark nets and shore seine nets is prohibited only in the Outer Channel of the Lagoon, aquaculture is banned in the entire Lagoon by the Supreme Court of India, and fishing is completely banned during November to January in the Nalabana Bird Sanctuary in the Central Sector of Chilika.

3.4.3. Direct Takes

There are no known direct takes of Irrawaddy dolphins in Chilika and dolphin meat is not consumed anywhere in the state of Orissa. The *Wildlife (Protection) Act 1972 of India* gives dolphins the highest level of protection and killing is prohibited. The penalties for violation of the law are imprisonment for a term not less than three years but which may extend up to seven years. There is also a fine of not less than 10,000 Indian Rupees (220 US$). For the second and subsequent offences, the term of imprisonment is three to seven years including a fine, which may not be less than 25,000 Indian Rupees (550 US$).

3.4.4. Incidental Takes

In Chilika, a high percentage of mortality is from entanglements in large mesh gill nets, seine nets and hook lines. The Chilika Development Authority Dolphin project has been in charge of the necropsy and carcass salvage program in Chilika since 2002. The project has estimated that about 15% of mortalities are associated with fishing net entanglement and 9% due to boat collisions while the remainder of cases is of unknown cause or not reported.

3.4.5. Pollution

Household wastewater and sewage from surrounding villages, fertilizers and pesticides from agricultural fields and aquaculture farms are the main sources of pollution in Chilika. None of these pollutants is thought to pose a significant threat at present levels (Finlayson et al. 2001; Pattnaik et al. 2007). A recent study to determine the status of toxic contaminants in Irrawaddy dolphins from Chilika found levels of organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers (Kannan et al. 2005) lower than the toxic threshold concentrations. The highest level of organochlorines found in the tissue was dichlorodiphenyltrichloroethane and its metabolites with a concentration of 10,000 ng/g lipid weight found in the blubber of an adult male dolphin. Hexachlorocyclohexanes were the second most abundant organochlorines followed by polychlorinated biphenyls. Concentrations of polychlorinated biphenyls in Irrawaddy dolphins were one to two orders of magnitude lower than the toxic threshold concentration of 8700 ng/g lipid weight that has been reported to elicit physiological effects in some aquatic mammals (Kannan et al. 2000). Because the Chilika Lake watershed is agricultural rather than urban and industrial in nature, polychlorinated biphenyl concentrations in Irrawaddy dolphins are not expected to be high. Kannan et al. (2000) warn that the levels of contaminants could exceed threshold levels if agricultural run off and oil pollution were not kept under control. I conclude that management plans for the lagoon should include regular monitoring of contaminants levels and mitigation of agricultural run-offs into the lagoon system.

3.4.6. Vessel Traffic

Daily passenger boats and fishing boats traverse at least nine defined routes in the Lagoon and are the only mode of transport across the Lagoon for the local populace. These boats, if motorized, operate at pretty slow speeds of ~11km/hr and are not likely to strike dolphins at such speeds. At the same time, operators of these boats do not keep a look out for dolphins. A passenger ferry carrying people and vehicles makes daily trips from 7am to 6pm along one route in the dolphin high density area (Outer Channel) of the Lagoon. Not all fishing boats use engines, but in some areas motorized boats are also used in the dolphin watching tourism industry. I provide details of vessel traffic involved in dolphin based tourism in Chapter 10.

3.4.7. Tourism

Dolphin watching tourism has increased in the lagoon without restrictions. For example, 331 boats operate from Satpada- the tourist centre of Chilika (Figure 2.1). Locally run dolphin watching associations use boats owned by fishers from twelve surrounding villages. To regulate the movement of boats inside the Lagoon, the Orissa Boat Rule, was enacted in March 2004. Under this rule, boats inside the Lagoon need to be licensed and each licensed boat needs to display the registration number affixed at a prominent place on the boat. This rule does not seem to change the way the tourism is managed in the Lagoon. Irrawaddy dolphins are given the highest level of protection by the *Wildlife (Protection) Act of India 1972*, but there are no regulations on the number of boats that can go out to look for dolphins per day. I present further details of the tourism industry in Chilika in Chapter 10.

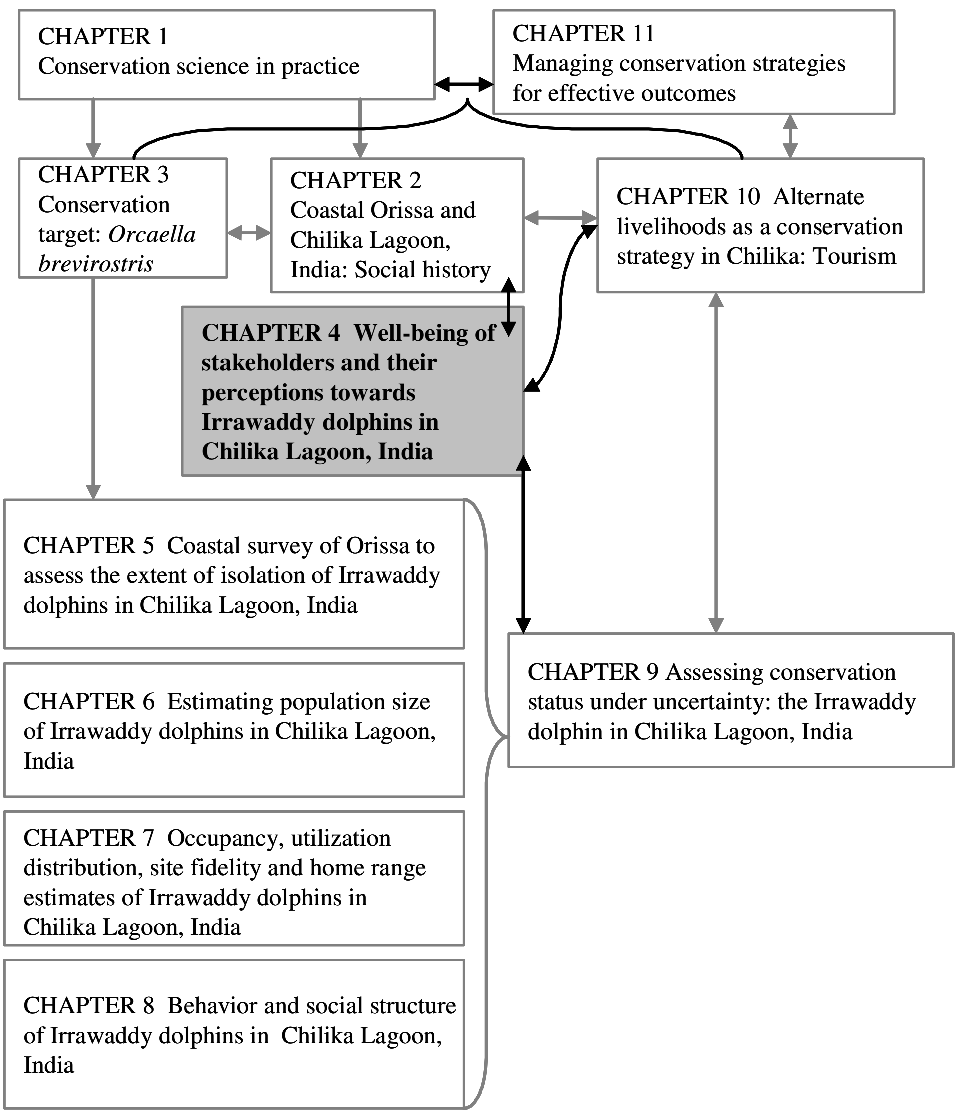
As explained in Chapter 1, my study aims to fill some of the gaps in current knowledge regarding Irrawaddy dolphins in Chilika Lagoon as the basis for a systematic assessment of the population. In Chapters 5 to 9, I focus primarily on the conservation and population ecology of the dolphins in Chilika. In Chapter 4 and 10, I emphasize the cultural and economic significance of the dolphins in Chilika.

3. 5. Chapter Summary

- The Irrawaddy dolphin is assessed globally as 'Data Deficient' by the IUCN, but five freshwater and brackish water subpopulations are Critically Endangered. There are large gaps in the life history information for the species.
- The species is found in isolated patchy populations and tends to occupy shallow, muddy coastal stretches, enclosed bays and lagoons, or freshwater river systems. The species has been recorded from the east coast of India, and in the tributaries of the Ganges in the Sunderbans Delta.

- Abundance estimates are available for four brackish water, three riverine and three coastal populations but comparing these results is challenging or establishing trends owing to the different methods used by the researchers.
- A small population of Irrawaddy dolphins is found in Chilika Lagoon in Orissa. A large human population depends on the Lagoon for resources and the dolphins thus face a range of threats from over-fishing to tourism, with the major threat in Chilika being entanglement in nets and other gear.
- Several measures have been taken to mitigate threats to the dolphins in Chilika, but these interventions may not necessarily decrease threats, and outcomes are yet to be assessed.

4 WELL-BEING OF STAKEHOLDERS AND THEIR PERCEPTIONS TOWARDS DOLPHINS IN CHILIKA LAGOON, INDIA



In human dominated environments such as Chilika Lagoon, effective species conservation and resource management depend largely on the perceptions and actions of the local stakeholders towards these issues. In this chapter, I provide information to guide co-management or community-involved conservation by investigating the social perceptions and knowledge of the local community in Chilika Lagoon. I used data collected through semi-structured interviews from 44 villages in the vicinity of Chilika Lagoon and identified the values attached to dolphins and resource management. I tested the data for differences in perceptions towards dolphins and discussed perceptions toward resource management. I hypothesized that factors like region, age and boat-type owned would influence interactions with dolphins and thus influence the perceptions of stakeholders towards conserving dolphins. I drew on the results from this Chapter to assess the conservation status of the Irrawaddy dolphin population in Chilika Lagoon in Chapter 9.

4.1. Introduction

Conservation projects have largely been based on anecdotal information rather than a thorough examination of the relevant issues and their outcomes (Sutherland et al. 2004). The IUCN Red Listing process is strongly relied upon for species and population level status assessments and is based fully on ecological data sets. The IUCN process was not designed to determine conservation priorities, and thus excludes the perceptions of local stakeholders and decision makers. Sutherland et al. (2004) developed a standard system to compare a collection of conservation case studies and suggested that qualitative data on the human component be part of the decision-making process. Several proponents of adaptive management and co-management of resources (Ostrom 1990; Berkes & Folke 1998; Salafsky et al. 2002) propose that the ‘social and natural’ are parts of a single socio-ecological system and suggest that nature conservation projects should consider both ecological data and stakeholder perceptions, values and knowledge of the resource to design effective management strategies. Although, the direct participation of stakeholders (Mathevet & Mauchamp 2005) in resource management is rooted in agro-forestry and sustainability science (Harding 1984; Jentoft et al. 1998; Marsh et al. 1997), the inclusion of stakeholder opinions and priorities into the design and implementation of a conservation program was not developed till the early 1990s (Agrawal & Gibson 1999; Armsworth et al. 2007; Rodríguez-Martínez 2008).

Biodiversity and species conservation outcomes have been poor in many cases where intrusive management strategies have ignored the knowledge and role of the community in resource management, or have chosen to exclude them from the resource (Agrawal & Gibson 1999). The success of long-term conservation objectives especially in human dominated regions largely depends on understanding the various functions of the ecosystem in relation to the human system. Acknowledging and accepting the role of human perceptions in decision-making (Knight et al. 2001; Redpath et al. 2004); Sutherland et al. 2004) provides a sound protocol for assessing the true success or failure of a conservation strategy (Mathevet & Mauchamp 2005). Evidence-based conservation which combines ecological data with a survey of social mechanisms, values and perceptions of local stakeholders is a socially acceptable and effective path for conservation managers. The involvement of target groups in finding solutions and making decisions is thus becoming increasingly important in many countries today.

As described in Chapters 2 and 3, Chilika Lagoon is home to a resident population of Irrawaddy dolphins. The Lagoon is unprotected from human use, apart from the region of Nalabana Sanctuary, which is closed to fishing during the months of November to January. Conservation of the Irrawaddy dolphins in Chilika Lagoon is a major concern to relevant local and international NGOs and local and national government bodies. Documenting the perceptions of the local stakeholders towards the species of conservation interest is thus highly desirable. In this chapter, I identify the values attached to dolphin conservation and natural resource management in Chilika. I hypothesize that region, age and type of boat owned influence the perceptions of stakeholders towards conserving natural resources including dolphins. I present the results as basic information to be considered by conservation agencies in developing an understanding of the scope of conservation in human-dominated regions like Chilika Lagoon. The RAMAS RedList software, built on the same concept as the IUCN Red List Criteria, offers the option of including human perceptions in a status assessment (Akcakaya & Ferson 1999). Accordingly, I use the results from this Chapter to inform the status assessment of the Chilika population of Irrawaddy dolphins within the IUCN Red List framework in Chapter 9.

4.2. Methods

4.2.1. Study Area

As outlined in Chapter 2, Chilika Lagoon is a brackish water lagoon/lake located in Orissa, India (19° 28'N - 19° 54'N and 85° 05'E – 85° 38'E; Figure 2.2). The Lagoon is a major source of food and income for more than 132 hamlets of varying size along its shores. More than 30% of fishing villages are actively involved in and dependent on fishing, aquaculture or other fishery related business ventures for their subsistence.

4.2.2. Interview Surveys

Community perceptions have been used successfully in reducing human-wildlife conflict and in co-managing natural resources (Conforti & Cesar Cascelli de Azevedo 2003; White et al. 2005; Mark Infield 2001; Lamb & Cline 2003; Udaya Sekhar 2003). The interview survey is a valuable tool for collecting knowledge regarding the perceptions of stakeholders and for analyzing the economic importance of a resource (White et al. 2005; Bunce & Pomeroy. 2003).The personal face-to-face involvement of an interviewee can elicit sincere participation, frequently more efficient for collecting information about people's knowledge and opinions than postal questionnaires (Murray 2003). Interviews with local communities have also been used to inform conservation strategies for Irrawaddy dolphins in Cambodia and Indonesia (Kreb 2000; Beasley 2008).

4.2.3. Development of Interviews

The objective of my interviews was to collect temporal and spatial information regarding local knowledge and perceptions of dolphins and resource management in Chilika Lagoon. I carried out a scoping study to form a relationship with fishers during my first field season (November 2004 to January 2005). I followed a converging-question structural approach with the help of a local counterpart. This type of interview starts with open-ended questions to initiate a discussion and then approaches closed ended questions to obtain specific information. The interview was thus semi-structured (Table 4.1). The interview questions included qualitative (What kind? /What Perceptions and feelings? /explain an answer) and quantitative (How much? / What percent? /to what degree?) questions.

Interviews followed the James Cook University (JCU) guidelines for interviewing Indigenous Peoples. Human ethics approval was obtained from JCU under approval reference A940. As a condition of the ethics approval, I obtained each interviewee's consent before initiating an interview, and a completed interview was regarded as successful. Interviews were stored as specified by the ethics guidelines.

4.2.4. Representation and Effort

Senior fishers from Balbhadrapura and Alupatna villages provided me with a list of the major fishing villages around Chilika. I followed this list such that all the four sectors of the lagoon were surveyed. The target interviewees were mainly adults (18 years and above) living close to the shores of Chilika and involved in fishery-related occupations (aquaculture, mollusc collectors, weed collectors, fishers). I selected interviewees by choosing houses in a zig-zag fashion, starting from the first house in the village where an individual was present and ready to participate. Individuals whom I met as a result of chance meetings at the village hall or tea stalls were also interviewed. The number of households per village ranged from 40 to 200, with the average being 150 households. To gain representation from each village, I interviewed a single individual from ten households in each village, unless limited by time or logistics. All the households I visited or individuals I approached were ready to be part of the survey, giving a 100% response rate. The interviews were facilitated by my local counterpart who spoke and read the local language, Oriya. All questions were asked in Oriya, a language that I understand and can speak enough to communicate.

4.2.5. Interview Method and Reliability

My counterpart was the primary interviewer, while I listened, took part in the conversation, noted answers and inquired further when needed. After introducing myself and my counterpart, and explaining the reasons for my inquiries, we initiated a directed conversation, following a set of questions (Table 4.1). The success of the interview depended on our ability to explain our objectives, to ask the question in the context of the study and to direct the conversation so that it stayed on track. Each interview lasted no more than 15 to 20 minutes which helped reduce fatigue for both the interviewer and the interviewee. During the interview, if the responses to an earlier question led us to a question at the end of the survey, the flow of information was not interrupted; the missed questions were brought up later. I wrote down the answers and recorded the flow of discussion in a notebook.

The interview was designed to be simple and translation error is negligible as the primary interviewer spoke and wrote both English and Oriya. The replies were discussed between the primary interviewer and me, to double check if the context of the question was understood by the participant. I also checked the reliability of the answers based on historical information, literature and other interviews from the region.

Each interviewee first provided his/her village name, age, family details and occupation (I gave the participant the option of not providing his/her name to maintain privacy). These responses led to discussions regarding occupation, and questions pertaining to occupation (usually fishing), monthly income and expenditure of households, which led to questions about the fisheries in Chilika Lagoon. By this time the participant was usually comfortable with us and we would bring up questions pertaining to dolphins, including the level of the respondent's affiliation towards dolphins (High, Medium, Low, Zero) and changes seen over time in the relative abundance and distribution of dolphins.

4.2.6. Data Collection and Analysis

Perceptions toward Dolphins

To investigate if the respondents from different regions of Chilika differed in their perceptions towards dolphins I classified the interviewees based on the location of their villages: Outer Channel, Southern Sector, Central Sector, and Northern Sector (Figure 4.1). I used the kind of boat owned as an index of wealth in order to determine whether socio-economic condition was an important factor in shaping local peoples' opinion towards dolphins and resource management. I found that people were hesitant to discuss their monthly or annual income and expenditure, and that such information was not reliably obtained from interviews. A participant who owned a motorized boat was classified in the highest socio-economic category. A participant who did not own even a simple wooden boat with oars or sails was classified into the lowest socio-economic category of fishers. I grouped respondents into six age classes (20-29, 30-39, 40-49, 50-59, 60-69 and ≥70 years) to investigate if age influenced perceptions towards dolphins in Chilika. I hypothesized that if traditional knowledge has been passed down through age categories, I would not find a difference in perceptions across age groups. Using this information, I tested the influence of participant age (continuous variable), boat type owned (ordinal variable) and region (ordinal variable) on Affiliation toward dolphins using a Classification Tree (Breiman et al. 1984). Classification trees are used for the analysis of a nominal response variable and multiple explanatory variables. Classification Trees can be used to find interactions between variables missed by other methods like simple regression, generalized linear models and generalized additive models. Trees also indicate the relative importance of different explanatory variables. I analyzed the data in R statistical software using the *mvpart* package for class based regression trees (R Development Core Team 2005). Tree size was chosen using the cross-validation method and the misclassification error (error/number of classifications per leaf) instead of the mean is calculated.

Distribution of Dolphins

To obtain information regarding the distribution of dolphins in Chilika lagoon, I inquired about how often dolphins had been encountered by the participant and if these encounters took place close to their village. Based on information from participants about dolphin interactions close to their villages, I created distribution maps of past and present dolphin distribution using ArcGIS software for comparison with boat-based sighting information from Chapter 6.

Well-Being and Habitat Quality

To obtain information about the influence of habitat quality on community well-being, I encouraged the respondents to talk about the status of their fish catch, habitat quality, restoration efforts and personal well being. Responses were transferred into an Excel data sheet where answers were collated using a binomial (Yes/No) format, textual format or ratings. Frequencies were calculated for each category of perception or answer to each question. Perceptions for each response are given in percentages calculated based only on those who answered the respective question.

Table 4.1. The semi-structured interview that was carried out in 44 villages around the lagoon.

1. Village Name, Age, Sex
2. Number of people in the household (M, F, Children)
3. Total number of earning members (M, F, Children)
4. Occupation of earning members (Fishing, Tourism, Service, Business, Fish/Shrimp trader, Agriculture)
5. Income/month per earning member from different occupations
6. Monthly expenditure (Household costs, Education, Extras)
7. Is the quality of life better today then it was 5 yrs; 10 yrs; up to 50yrs ago?
8. Any alternate options for earning a livelihood? If so, what are they?
9. What is the population of your village? What are your perceptions regarding this observation?
10. How has your fish/shrimp catch been? What are your perceptions regarding this observation?
11. What kind of fishing do you do? Area?
12. Are you happy with the new nets that are being used in Chilika?
13. Are dolphins important to you? How- Fishing? Company? Status symbol of Chilika? Stories? High, Medium, Low, Zero
14. What are your observations regarding trends in abundance of dolphins?
15. Do you want dolphin tourism in Chilika?
16. Are you happy with the way the dolphin watching association is running?
17. What are the causes for dolphin mortality in the lagoon? Engines? Nets? Disease? Starvation? Salinity?
18. What would you want changed to make the quality of life better for you?
19. Are you happy with the way the lagoon is being managed?

4.3. Results

4.3.1. Demographics of Participants

Of the 132 villages in the vicinity of Chilika Lagoon, 44 villages (33%) (Figure 4.1) were surveyed in this study. Four hundred individuals were interviewed over a period of two years (2004-2006) with an average representation of 10% per village. The villages surveyed represent the South, North, Central and Outer Channel regions as shown in Figure 4.1. Fourteen villages were visited in the South Region, 13 villages in the North Region, 11 in the Outer Channel Region, and six villages in the Central Region (Figure 4.1). Women are not directly involved in fishing activities and were therefore not interviewed for this survey.

I obtained age information for 386 participants who ranged from 18 to 90 years of age. More than 50% of respondents were between 30-50 years of age. Only 15% of the participants were between the ages of 60-90 years, 85% were between the ages of 20-60 years (Table 4.2).

Table 4.2. The age distribution of interviewees from 44 villages around Chilika Lagoon

Age (Years)	% of Interviewees
18-20	2
20-30	16
30-40	27
40-50	29
50-60	15
60-70	6
>70	5

4.3.2. Personal Well-Being of Participants

Of the 400 participants interviewed, 98% of the respondents stated that fish catch had been steadily falling in the last 10 to 15 years. Fishers said that present catches were less than 70% of what they caught 15 years ago. For 95% of the participants, fish catch had fallen to less than half in the past ten years. All these participants said that their life was much better 15 years ago. One respondent stated that,

"Fish catch has decreased so much that now we live in debt. We do not have any savings".

When asked about personal well being, another participant stated that,

"(personal well-being) Very low, as conflict between fisherman and non-fisherman is very high in Chilika, and fish catch is low, so our income has fallen by more than 70%"

Another participant stated that,

"Our personal well being is connected to Chilika Maata[3]. Whatever we get in our nets everyday is what we live on."

[3] Mother

When asked whether they needed alternate sources of livelihood like tourism, all the respondents answered in the affirmative, but said that fishing would always remain their primary occupation. A participant said that,
"Tourism is good for income but bad for Chilika and for fish, as engines pollute the water"

All respondents said that fishing was an inherited occupation and would always remain their main source of income. Those community members who were involved both in tourism and fishing, earned more than double the amount earned from fishing alone (Table 4.3).

Table 4.3. Average income of participants involved in tourism and fishing occupations based on interview surveys

	Fishing and Tourism	**Fishing only**
% participants (n=400)	17 %	83%
Average Monthly income (US$)	145(Min=60,Max=235) 6000INR	54(Min=5,Max=105) 2500INR

4.3.3. Participant Perceptions of Natural Resource Management

While discussing the causes for fall in fish catch per individual, some of the common themes were ' pollution', 'increase in fishing population', 'siltation and choking of lagoon', 'Gheri jaal'(aquaculture enclosures), 'Zero net' (fine mesh size gill net) 'Alimi jaal'(shore seine net) and 'new sea mouth'(Table 4.4). The increase in the size of the fisher populations was also perceived to decrease the catch per unit effort.
Participants frequently stated that,
"In Chilika fish catch is decreasing but the number of people fishing has increased"

A very common theme that arose was about ownership of fishing rights in Chilika and a participant voiced these concerns by stating that, *"Shrimp aquaculture and lease system should be removed, but till that happens fishers should also have an equal right to carry out aquaculture"*

Another participant very passionately said that:

"Give Chilika back to the people and we will take care of it"

Of the 400 participants, 67% said that pollution and motorized engines have resulted in loss of habitat quality and hence a decrease in fish catches. A participant said,

"Fish are scared of engine noise and move away, and the oil even spoils the water"

Fifty-seven percent of the 400 participants thought the location of the new sea mouth, the natural closure of the old sea mouth and silting of the Palur channel were responsible for the fall in fish catches.

"Chilika is slowly dying due to siltation and aquaculture"

Gheri (aquaculture enclosures), Zero (fine mesh size gill net) and Alimi nets (shore seine net) were thought to be responsible for catching all fish, shrimp and roe before these resources can enter the Lagoon.

When asked about nets a participant said,

"They lay out big nets near the sea mouth that catches all the fish, then how can we get anything to catch?"

Another participant stated,

"Shrimp aquaculture has killed traditional fishing practices and in some places choked channels such that a large number of fish and crab species have disappeared"

While discussing the 2001 restoration of Chilika created by dredging a new mouth to the sea, 55% of the respondents stated that the location of the sea mouth was detrimental to fishers as the resultant strong currents did not allow fish and roe to stay inside Chilika. Rather the currents carried the fish and roe all out to sea with the tide. Another 35% were neutral about the opening of the sea mouth as its location was far away from their village and 9% stated that the new dredged mouth was good because 1) it sent fish to the northern sections of the lagoon where silt had choked most channels, and 2) the sea mouth was required to prevent further choking of the lagoon.

When asked if they were interested in conserving natural resources like fish and dolphins for the future, 34% of the 400 participants thought it was not necessary to conserve dolphins but that it was necessary to sustain fish resources.
When asked how to best conserve fish populations one participant explained that,
"We should keep the channels free of nets to allow the free flow of fish and nutrients"

Of the 400 participants, 66% said they were keen on conserving both dolphins and fish but that they did not know how to do so without reducing their own income.
A middle aged participant said,
"If dolphins die in nets, it is by accident. Our ancestors tell us we will have nine years of bad luck if we kill a dolphin"

Table 4.4. The causes for fish decline as stated by participants from 44 villages around Chilika lagoon, India. Appendix

Cause	% Participants
Pollution and motorized engines	67
Location of the new sea mouth	57
Fishing population increase and non-fishers	50
Silting of channels	24
Gheri (aquaculture enclosures)	36
Zero net (zero mesh size gill net)	35
Alimi net (shore seine net)	21
Munni net (bag net)	5
Dubbi net (trammel net) (small to medium mesh gill net)	3

4.3.4. Participant Perceptions of Distribution and Relative Abundance of Irrawaddy Dolphins

Out of the 44 villages visited, nine reported never having seen dolphins close to their village shores. Twenty-three villages reported that 15-20 years ago, dolphins were found in the vicinity of their village but now one had to go to the deeper sections of the lagoon to see them. Twenty-three villages reported that dolphins were seen both in the past and today in the vicinity of their village (Figure 4.1B). I mapped these locations to illustrate the differences between current and historical distribution of dolphins in Chilika Lagoon (Figure 4.1C).

A participant from the Northern Sector of Chilika said that,
"They used to be here close to the village many years ago, but now they are not here anymore"

Ninety-four percent of the participants reported a decrease in the number of dolphin groups encountered during fishing trips. A participant interviewed from the Southern Sector of Chilika said that,
"The number of dolphins in Chilika has reduced in the past few years and even the number of animals seen in a group has reduced"

While inquiring about the cause for dolphin mortality, 20% of participants said they were unaware of the cause, while 62% stated that incidental catch in fishing nets was one of the main causes of mortality in dolphins. Other causes for mortality were loss of habitat quality and size due to siltation and aquaculture (27% of participants) and disturbance by motorized boats (29% of participants). A few participants remarked that disease, old age and encounters with sting rays and sharks also cause mortality of Irrawaddy dolphins in Chilika.

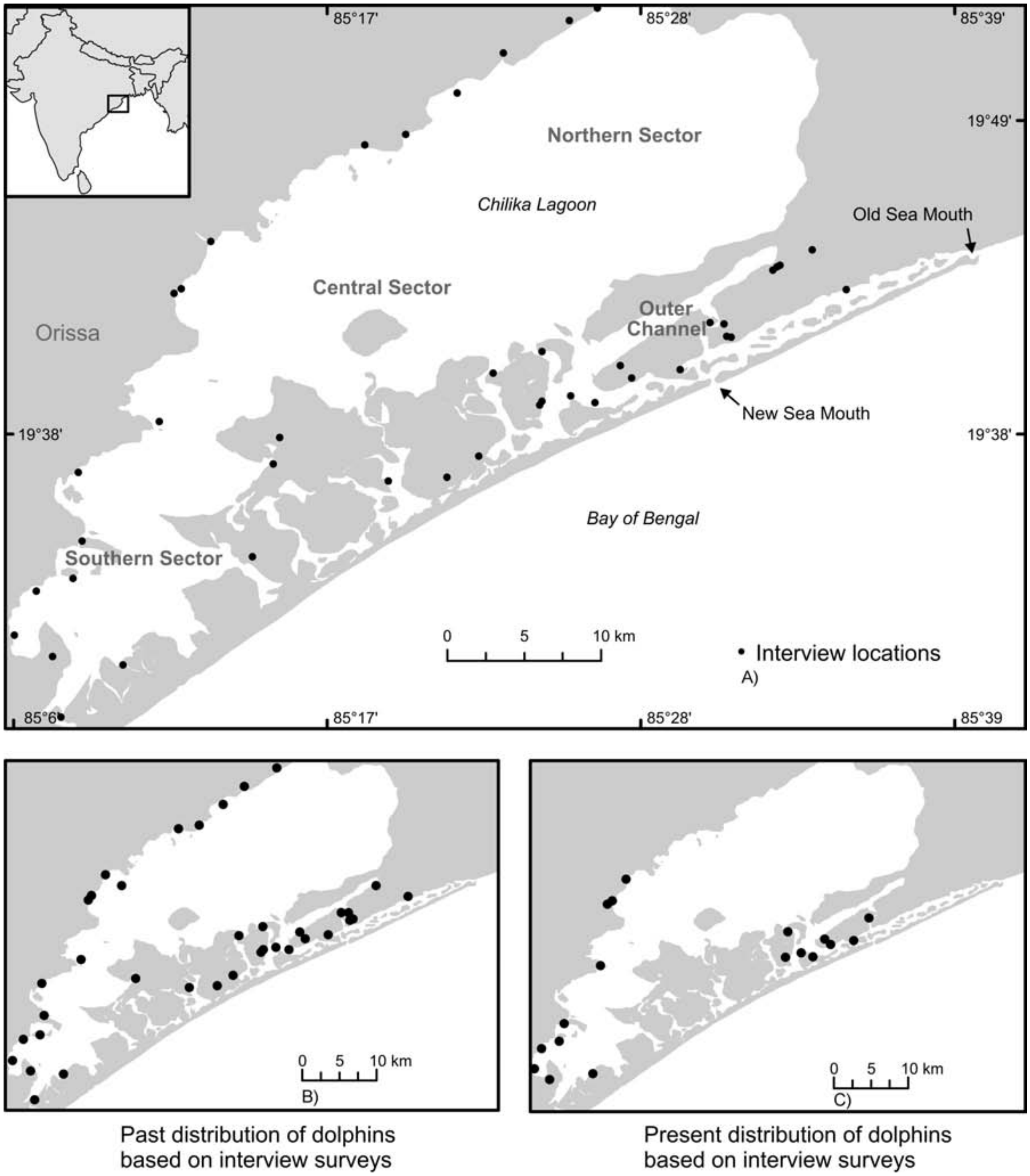


Figure 4.1. A) Villages where I conducted interviews around Chilika Lagoon to obtain perceptions from the local community regarding the distribution of Irrawaddy dolphins. Past (B) and present (C) dolphin distribution based on 400 interviews with fishers from 44 villages around the Lagoon suggested that the range of occurrence has decreased substantially.

4.3.5. Affiliation towards Dolphins based on Region, Age and Boat Ownership

The Classification Tree indicates that participants from the Outer Channel (code: Outer.Channel≥0.5) were likely to show high affiliation toward dolphins (high=4). If they were not from the Outer Channel but were from the Southern Sector, participants older than 45 showed a high affiliation, whereas those younger than 45 years showed low affiliation toward dolphins. Individuals from the Northern and Central Sectors were likely to show high affiliation towards dolphins only if they owned a boat (code: no.boat<0.05 motorized or non-motorized). There were not enough data to draw this inference as individuals who did not own a boat showed medium affiliation. There was no significant difference in the degree of affiliation towards dolphins between age groups 20-90 years and boat ownership in the Outer Channel. The results from the Classification Tree should be treated with caution as the misclassification rate is high at 0.38, i.e. 38% of the data were not classified correctly. But the results are indicative of the importance of the village of the respondents in their perceptions towards dolphins.

4.3.6. General Perceptions of Dolphins

When asked about their general perceptions regarding dolphins, a 90 year old man said with calm resolve:

"Dolphins are a blessing from Goddess Laxmi, as a sign of wealth and prosperity - if there are no dolphins, there will be no Chilika"

A participant of the Outer Channel provided the following example of a frequently voiced opinion mostly in the Outer Channel and Central Sector:

"Dolphins are a sign of fish for us. If there are no dolphins, there will be no fish. They help us fish and are a blessing of God."

A participant from the Southern Sector described his encounters with dolphins and said that:

"Dolphins are very nice to see, they make me smile every time I see them"

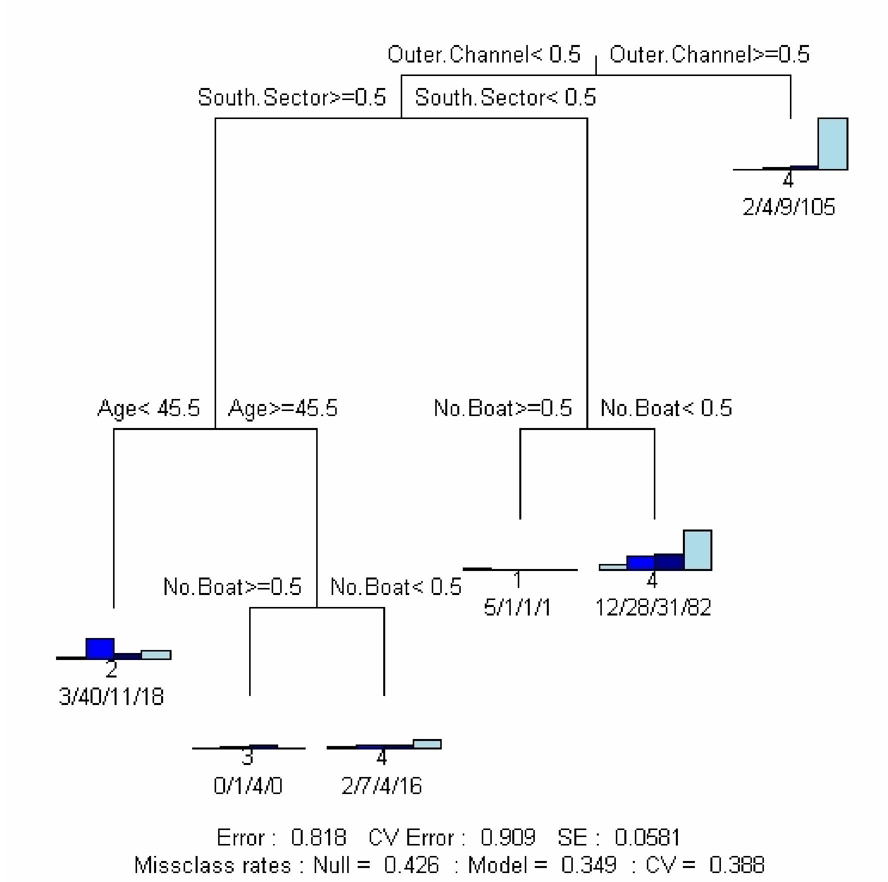


Figure 4.2. Classification Tree for Affiliation data across four groups using a cross validation algorithm to choose the tree size. Affiliation groups are 1 to 4 stand for None, Low, Medium and High respectively. Below each branch is a histogram showing the distribution of the affiliation group for that branch, followed by the predicted class and the number of observations in each class. Branch length is proportional to the improvement in the fit.

4.4. Discussion

Current and Historical Distribution

The results of interview surveys indicate a change in the distribution of Irrawaddy dolphins in Chilika with a significant decrease in their range. Ninety-four percent of the 400 participants suggested that the population of dolphins in Chilika is 'decreasing'. The result concurs with empirical data (2004-2006) obtained from carcass collection which suggest a mortality rate of 7% p.a for Irrawaddy dolphins in Chilika Lagoon (Chapter 2).

The results from the interviews also suggested that participants believed that the major causes for mortality in dolphins were fishing nets, habitat loss and motorized boats. Decrease in their range and abundance has been documented for riverine and lagoonal populations of Irrawaddy dolphins in Cambodia and Vietnam where the species range in the Mekong has shrunk over time and the population is perceived by local communities to be decreasing (Beasley 2008). Whether this decline is due to fisheries or disease-related causes, or from changes in prey availability is yet to be elucidated.

The interviews I conducted indicated that in the past Irrawaddy dolphins in Chilika Lagoon used natural channels and shorelines of the South and Central Sectors, along the western shores of Chilika. Formerly, the active Palur Channel in the southern part of Chilika brought fish and roe from the sea, and thus maintained the flow of water and nutrients in these channels of the Southern and Central Sectors of the lagoon. Presently, the Palur Channel is very narrow, choked by silt and meanders for at least 20km before it reaches the sea. So, if the distribution of dolphins in Chilika is influenced by prey distribution, the decrease in prey supply from the choking of the Palur Channel could be the cause for the change in distribution suggested from the interviews. Fishing nets are believed to cause most dolphin mortality. The reduction in habitat suitable for both nets and dolphins could exacerbate net mortality by increasing the chance of encounters between dolphins and nets, suggesting that ecosystem based management of the lagoon, focusing on the habitat quality and management will be a key factor in sustaining dolphins in Chilika.

Affiliation towards Dolphins based on Region

The Classification Tree (Figure 4.2) suggests that fisher perceptions towards dolphins differed primarily based on the region where the participant was based, demonstrating how experience could play a role in developing affiliation. If fishers interact little with dolphins, their experience is minimal and affiliation is low. I found that the Outer Channel residents showed highest affiliation whereas the residents of the Northern Sector showed the least affiliation with dolphins. This result can be explained by the apparent absence of dolphins currently in the Northern region as seen in this chapter and in Chapter 6. The Southern and Central Sectors showed mixed results which could be a result of low numbers of dolphins sighted and could also be connected to the types of fishing gear used in these areas. The connection between fishing gear used and affiliation towards dolphins needs to be explored. If gear detrimental to dolphins are being used, the fisher may choose to decrease his affiliation, thus not threatening his sustenance and livelihood. These results suggest that conservation strategies may need to vary in different regions of Chilika. While managing or regulating fisheries to conserve dolphins, it would be necessary to include the value of experience and sustenance to avoid non-cooperation from fishers. In the Outer Channel, conservation awareness programs and boat traffic management to avoid dolphin mortality could be the strategy to use. But in the Central and South, fisheries management might be the strategy to use. Such a mixed strategy approach inclusive of local stakeholder opinion and voluntary participation is likely to produce positive results.

Affiliation towards Dolphins based on Age

The Classification Tree (Figure 4.2) suggests that age influenced affiliation toward dolphins in the Southern Sector of the lagoon, where individuals over the age of 45 showed higher affiliation toward dolphins than those younger than 45. Age did not influence perception towards dolphins in the highly affiliated region of the Outer Channel or in the North and Central Sectors. I was expecting older age groups to be highly affiliated to dolphins across all the regions. This result suggests that traditional values and myths are being transferred across generations is most of the regions in Chilika.

Affiliation towards Dolphins based on Boat Ownership

Perceptions toward dolphins also did not differ due to the kind of boat owned by participants in the Outer and Southern Sector of Chilika. The Classification Tree suggests that respondents who were from the Northern and Central Sectors of Chilika differed slightly in their affiliation towards dolphins based on boat ownership. I had expected that fishers with motorized boats would be involved in tourism activities or would be able to encounter dolphins more often due to the area the fisher can cover in a motorized boat. The results suggest that involvement in tourism activities may bias affiliation towards dolphins and that little experience around dolphins due to not owning a boat could decrease affiliation over time.

Implications of Local Perceptions and Knowledge on Conservation Management

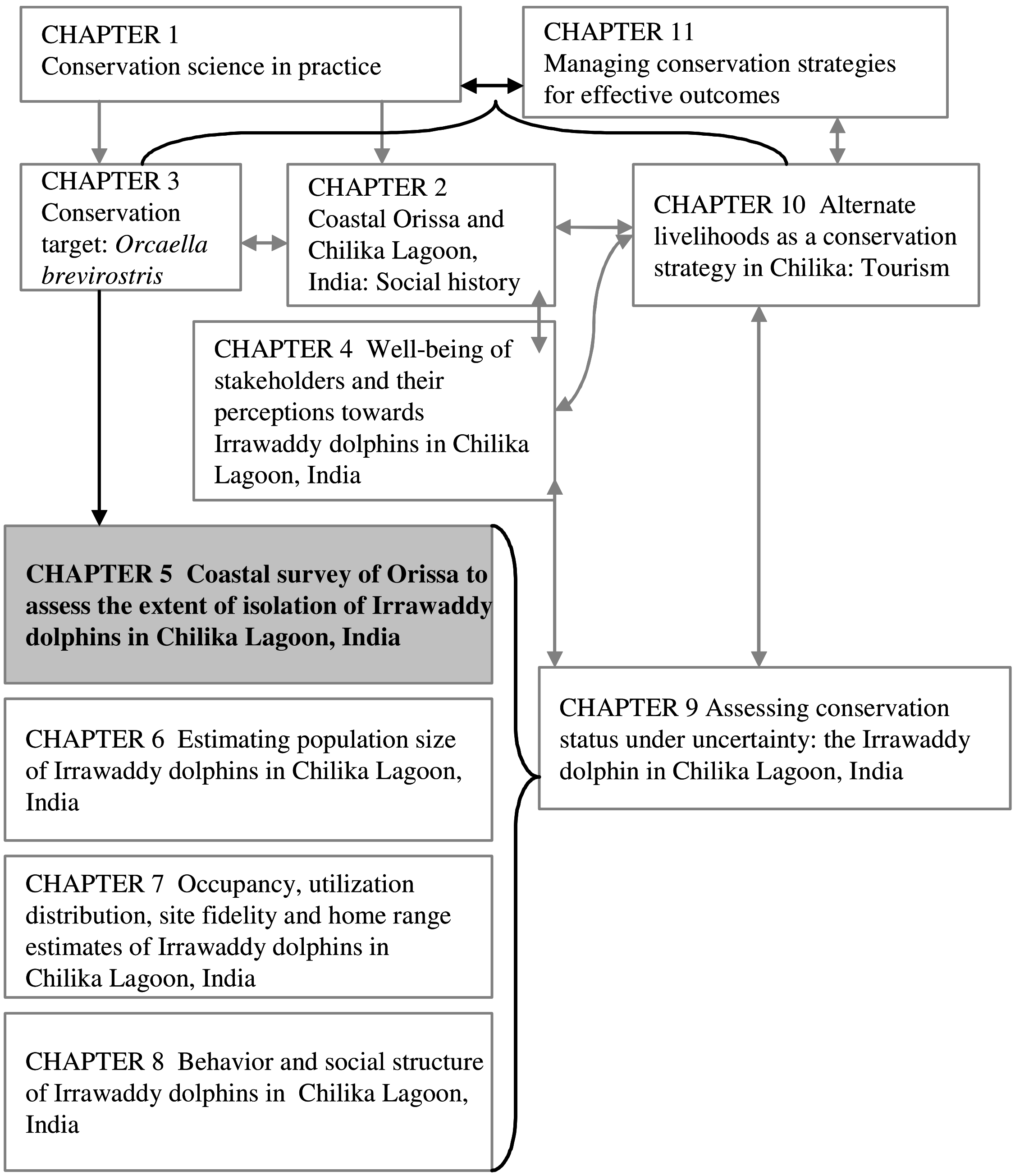
The results of my interviews show that communities in Chilika have recently experienced a fall in fish catch and a consequent decrease in personal well-being. It will be necessary to take the socio-economic circumstances of the people of Chilika into account in designing conservation actions to prevent further damage to the personal well-being of the local people.

Local people in Chilika like to observe dolphins, like to have them in their vicinity when they go fishing and to an extent revere dolphins. These are positive signs for conservation and should form the basis for future dialogue in the fields of awareness building, innovative solutions and co-operation towards conservation aims. Recognizing the prevalent knowledge and concerns can help decisions makers and conservation practitioners design conservation priorities for the future that will be more robust to sudden changes in the socio-ecological system. Co-management which links livelihoods or resource use to conservation, largely depends on the social and economic well being of the communities involved (Agrawal & Redford 2006) while also protecting or sustainably harvesting the resource. Enterprise-based conservation (e.g., tourism development), if successful, could positively reinforce the direct involvement of the community in Irrawaddy dolphin conservation planning in Chilika. In Chapter 10 of this thesis, I will explore in detail the dolphin-based tourism industry in Chilika and how it could help foster conservation goals.

4.5. Chapter Summary

- I interviewed 400 participants from 44 of 132 villages surrounding Chilika lagoon to obtain perceptions of natural resource management, personal well-being and dolphin distribution and conservation.
- The distribution of Irrawaddy dolphins in Chilika based on interview surveys indicates a reduction in range which could be caused from changes to the Lagoon.
- Ninety-four percent of participants reported a decrease in the number of dolphin encounters over the past 10 years.
- Sixty-two percent of participants suggested that incidental catch of dolphins in fishing nets is one of the major causes of mortality in dolphins.
- Perception towards dolphins differed significantly based on the region from where the participant was based. The most positive perceptions of and highest affiliation towards dolphins was found in residents of the Outer Channel.
- Ninety-eight percent of participants stated that fish catch had fallen to less than 70% in the past 10 to 15 years and that their life was much better 10 to 15 years ago.
- Of the 400 participants, 56% thought the location of the new sea mouth, natural closure of the old sea mouth and silting of the Palur Channel were responsible for the fall in fish catch.
- Thirty-four percent of participants thought it was not necessary to conserve dolphins but it was necessary to sustain fish resources, whereas 66% said they were keen on conserving both dolphins and fish.
- Local people in Chilika generally like to observe dolphins, like to have dolphins in their vicinity when they go fishing and to an extent revere dolphins in most parts of Chilika.

5 COASTAL SURVEY OF ORISSA TO ASSESS THE EXTENT OF ISOLATION OF IRRAWADDY DOLPHINS IN CHILIKA LAGOON, INDIA



Irrawaddy dolphins in Chilika Lagoon are socially valuable to local communities and the population is important at a socio-ecological scale. In this Chapter, I use the data collected from a vessel based coastal survey of Orissa along with carcass salvage data and a literature review to assess if Irrawaddy dolphins are found outside Chilika Lagoon and along the coast of Orissa. This information is required to provide evidence, that at least in recent years and during my research project, Irrawaddy dolphins have remained inside the lagoon, isolating the sub-population from other populations outside the Lagoon. I also try to identify the closest outside population of Irrawaddy dolphins to Chilika Lagoon based on carcass information and different habitat types found along the coast. Assessing the degree of isolation of the population will help determine the conservation status and management needs of the population.

5.1. Introduction

Very few systematic vessel-based surveys have been carried out to document the status of cetaceans and their distribution in in Indian waters (Kumaran 2002; Sutaria & Jefferson 2004; Tripathy & Choudhury 2004). With the exception of the population in Chilika lagoon, almost all records of Irrawaddy dolphins from India are limited to stranding or incidental catch records (Kumaran 2002). Twelve species of cetaceans have been recorded in the Northwest Bay of Bengal (the coasts of Orissa and West Bengal in India and Bangladesh). These species are : *1) Stenella longirostris, 2) Sousa chinensis, 3) Stenella attenuata, 4) Delphinus capensis tropicalis, 5) Neophocaena phocaenoides, 6) Tursiops aduncus, 7) Balaenoptera edeni, 8) Balaenoptera physalus, 9) Peponocephala electra, 10) Kogia breviceps, 11) Platanista gangetica, and 12) Orcaella brevirsotris* (Kumaran 2002; Sathasivam 2002; Smith et al. 2005). The records are mainly from carcasses, some of which could be misidentified (Kumaran 2002). The Sunderban Delta and coastal waters of West Bengal and Bangladesh host populations of the endangered Ganges River dolphin *P. gangetica* and the Data Deficient Irrawaddy dolphin *O. brevirostris* (Smith et al. 2005; Smith et al. 2006)(See Chapter 3)

To assess if the population of Irrawaddy dolphins in Chilika is geographically isolated, I present results from a single systematic survey of the coastline of Orissa, at the northwest margin of the Bay of Bengal. In this chapter, I use the data collected from the vessel based coastal survey of Orissa along with carcass salvage data and a literature review to assess the coastal cetacean diversity of Orissa and to evaluate if a coastal population of Irrawaddy dolphins is found in this region. I also describe environmental features along the coast to identify where the next closest population of this species is likely to occur.

5.2. Methods

5.2.1. Study Area

The coast of Orissa extends over ~480km (Chapter 2, Figure 2.1). As explained in Chapter 2, three seasons typically affect the oceanography of the coast: the North East monsoon (October to January), the South-West monsoon (June to September) and the fair weather period (February-May). Topography varies along the coast with 57% sandy beach, 33% mud flats and 10% marshy (Ahmad 1972; Kumar et al. 2006). Details of the coastline are provided in Chapter 2.

5.2.2. Vessel Survey

Boat-based line transect methodology was used for the surveys. The coast of Orissa (N19.15^{o} E84.88^{o} to N21.571^{o} E87.53^{o}) was surveyed in December 2004 from an elevated observer platform 4m above sea level using a 12m trawling vessel (Figure 5.1). The nearshore waters of the Gahirmatha Marine Sanctuary were surveyed opportunistically from the Orissa Forest Department's Sea Turtle Monitoring vessel (12m vessel with elevation of 4m) in March 2005. The mouths of three rivers in North Orissa were surveyed in February and March 2005 using 4.2m fishing vessels.

A zigzag survey design (Figure 5.1) was used for the nearshore survey, to cover the region uniformly across the depth gradients in a practical time frame. The lines were designed to cover waters less than 25m deep while searching as close to river mouths as possible. Some deviations from track lines were necessary to avoid rocks or shallows.

The first portion of the coastal survey took place from the 8th to 13th of December 2004. We surveyed south of Paradeep port, covering the mouth to Chilika Lagoon. The second portion of the survey took place from the 15th to the 19th of December 2004 and covered the region north of Paradeep as well as shallow and muddy waters near the Sunderbans (Figure 5.2). Survey lines on the return trips were different in the two sectors because of differences in bathymetry. During the outward survey, an average maximum distance of 6.9km from shore (SD=1km) was searched. During the return survey an average maximum distance of 30km from shore was searched in the region north of Paradeep waters owing to the very shallow bathymetry and broader continental shelf. On the return legs south of Paradeep and around the mouth of Chilika, we travelled at an average distance of 0.6km from the shoreline, searching specifically for Irrawaddy dolphins at the mouths of Rushikulya and Devi Rivers and Chilika Lagoon.

Figure 5.1. The medium sized trawler used for the boat-based survey along the coast of Orissa.

The research team consisted of three primary observers with 7x50 binoculars searching the water to the horizon or the closest water line from the elevated platform on the boat (Figure. 5.1). One primary observer searched 10º in front of the bow and recorded data and one observer on each side of the boat searched 10^{o} to 90^{o} on his/her respective side. A fourth observer recorded environmental variables – temperature, salinity, pH, wind conditions, and depth, every 10min on the survey line and at the location of each sighting. Search effort was limited to wind conditions ≤ Beaufort 3. Observer height varied from 1.57 to 1.76m.Every time a school of dolphins was sighted, the school was approached to record data on species, school size, school behaviour, location coordinates and environmental variables.

5.2.3. Review of Carcasses from the Region

Data on sightings and carcasses were collected by visiting six coastal sites along the coast and one Forest Department camp at Gahirmatha. These visits helped establish a network of individuals who could provide information about any new carcasses washed ashore during 2004-2006. The villages were selected in the vicinity of river mouths along the coast of Orissa-Ganjam beach, Arakuda village-Chilika, Puri beach, Astaranga village, Agarnasi forest camp and Baleshwar beach (Figure 5.1). Interested individuals were provided with a camera and data sheets to collect morphological and photographic data when carcasses were washed ashore. Identification guidelines were also provided to help identify common coastal species of the region. Finally, both published and anecdotal reports of dolphin carcasses and strandings recorded from the region were reviewed to locate regions where Irrawaddy dolphins could be found.

5.3. Results

5.3.1. Vessel Survey

The coastal survey comprised 89 hours of search effort covering a total distance of 770.3km at an average speed of 9.3km/hr. In addition, Gahirmatha Marine Sanctuary was surveyed in February 2005 with a total search effort of 11hr and 42 min, covering 42 km of transect line. Surveys took place in daylight hours between 7:00am and 4:00pm (local time) during medium and high tide, and in Beaufort conditions 0-3. Water depth ranged from 2.7m to 33.1m, salinity ranged from 21ppt to 34ppt, temperature ranged from 21.6° to 24.0° and pH ranged from 7.2 to 7.6 (Table. 5.1).

Irrawaddy dolphins were not sighted during the coastal survey. Four species of cetaceans (i.e., four schools of *Sousa chinensis* and two schools of *Neophocaena phocaenoides*, and one school each of *Stenella longirostris* and *Tursiops aduncus)*, were encountered (Figure 5.3, Table 5.2). *S. chinensis* was found close to the shore and river mouths and in waters less than 10m deep whereas *N .phocaenoides* was found in waters less that 17m deep. Single sightings of *T. aduncus* and *S. longirostris* were in depths of ≥19m. All sightings occurred in water of salinity ≥ 25ppt, temperature ≥24° and pH 7.3 to 7.6. Only one school of S. *longirostris* was recorded south of this region whereas one *T.aduncus* school was the only encountered in the north.

The mouths of the three main rivers north of Chilika, were surveyed in February and March 2005 as follows- Subernarekha River (total search effort-2:00hrs, 19km; 16km upstream), Budhabalanga River (total search effort-1:32 hrs, 20km; 6km upstream), and Devi River (total search effort- 1:45hrs, 17km; and 10km upstream). One school of *S.chinensis* was sighted at Devi River mouth in March 2005. No dolphins were sighted in the other two rivers.

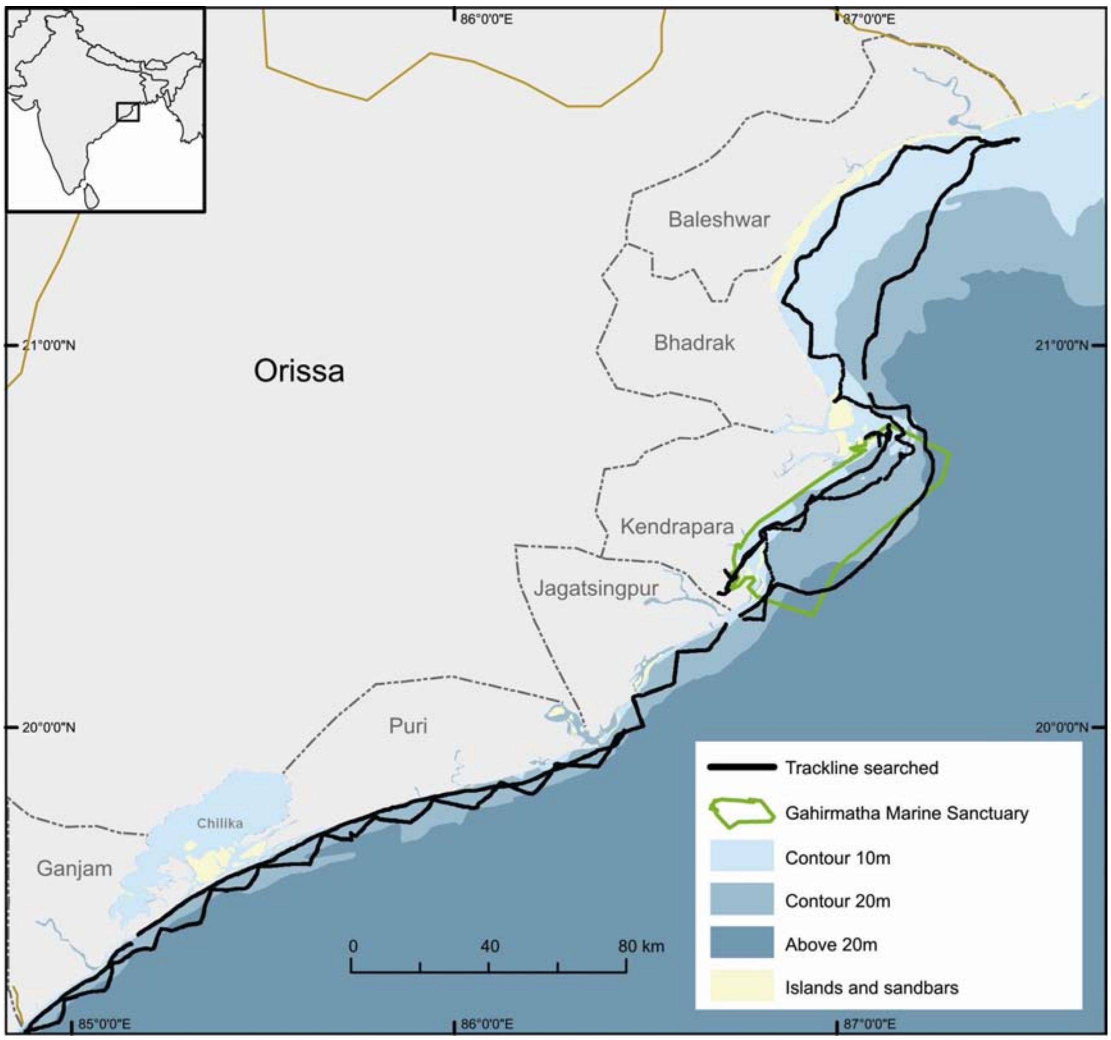


Figure 5.2. The coast of Orissa showing the boat-based coastal survey track in relation to Chilika Lagoon.

Table 5.1. All records of odontocetes from the coast of Orissa including the systematic survey, opportunistic sightings and carcass records (excluding Chilika Lagoon)

Species	Year /Type	Region (number of individuals)	References/pictures-pers. comm
Sousa chinensis	1983; Dead	Gahirmatha Marine Sanctuary (4)	James et al. 1989;
	1984; Dead	Gahirmatha Marine Sanctuary (3)	James et al. 1989;
	1985; Dead	Gahirmatha Marine Sanctuary (2)	James et al. 1989;
	1987; Dead	Gahirmatha Marine Sanctuary (4)	James et al. 1989;
	1999; Live	Gahirmatha Marine Sanctuary (5)	D. Sutaria
	1999; Live	Gahirmatha Marine Sanctuary (3)	D. Sutaria
	2000; Live	Gahirmatha Marine Sanctuary (15)	D. Sutaria
	2004; Live	Jagatsinghpur (15-20)	Table 5.3
	2004; Live	Gahirmatha Marine Sanctuary (70-100)	Table 5.3
	2005; Live	Gahirmatha Marine Sanctuary (3-5)	Table 5.3
	2005; Live	Puri-Devi River (5-7)	Table 5.3
	2004; Dead	Ganjam-Rushikulya River mouth (2)	D. Sutaria
	2005; Dead	Devi River mouth (1)	D. Sutaria
	2006; Dead	Devi River mouth (1)	D. Sutaria
	2007; Dead	Dhamara (2)	P. Mohapatra
Delphinus capensis tropicalis	1987; Live	Paradeep (12)	Jayaprakash 1995
Stenella longirostris	2004; Live	Puri coast (30-40)	Table 5.3
Orcaella brevirostris	1987; Dead	Gahirmatha Marine Sanctuary (1)	James et al., 1989
	2001; Dead	Puri-Devi River mouth (1 skeleton)	NHM Bhubaneswar
Tursiops aduncus	1992; Dead	Ganjam-Gopalpur (1)	Chandrashekhar 1993
	2004; Live	Baleshwar (5-7)	Table 5.3
	2006; Live	Gahirmatha Marine Sanctuary (15)	A. Fernandes Greenpeace India
Neophocaena phoceanoides	1986; Dead	Gahirmatha Marine Sanctuary (2)	James et al. 1989
	1987; Dead	Gahirmatha Marine Sanctuary (2)	James et al. 1989
	1999-2000 Dead	Gahirmatha Marine Sanctuary (4)	D. Sutaria
	2004; Live	Kendrapara (3-4)	Table 5.3
	2004; Live	Puri (2-3)	Table 5.3
	2005; Dead	Agarnasi (1)	Table 5.3, Rajnagar Forest Dept.
	2005; Dead	Puri coast (1)	Bichi, Astaranga
	2006; Dead	Bhadrak-Dhamara (2)	P. Mohapatra
	2007: Dead	Puri coast (1)	Chilika Development Authority 2007

Table 5.2. Descriptive statistics for depth, salinity,temperature and pH collected during the coastal survey

	Depth (m)	**Salinity (ppt)**	**Temperature °C**	**pH**
Mean	14.58	27.57	23.96	7.40
Minimum	2.70	21.00	21.60	7.20
Maximum	33.10	34.00	25.30	7.60
Standard Deviation	6.11	2.34	0.77	0.08
Standard Error	1.02	0.61	0.37	0.12
Coefficient of Variation	7.05%	2.21%	1.53%	1.65%

5.3.2. Mortality Records

Twenty-three fishers near three river mouths (Budhabalanga, Subernekha, Chandipur) and along the coast in North Orissa were interviewed about species sightings or carcasses found along the coast. All respondents spoke of the presence of black animals without a fin presumably *N. phocaenoides* or larger light-pink coloured animals with a fin, presumably *S. chinensis.* None of the fishers mentioned dolphin meat being used for local uses such as personal consumption or shark bait.

A total of eleven mortalities were reported by the network I set up along the coast and by knowledgeable correspondents. I assessed six fresh carcasses (four *S. chinensis* and two *N. phocaenoides)* and skeletal remains of one *O. brevirostris* at Astarang (Figure 5.2), while the other four animals (two *S. chinensis* and two *N. phocaenoides*) were identified from photographs. All animals recorded were adults and it was difficult to assess the cause of death as we did not carry out a necropsy (lack of infrastructure and required permissions were not available). Table 5.3 lists both published and unpublished reports of odontocetes found along the coast of Orissa from 1983-2006 and suggests an unconfirmed possibility that Irrawaddy dolphins occur in Gahirmatha Marine Sanctuary 150km north of Chilika.

Table 5.3. Records of cetacean species sighted along the near shore waters of Orissa from my systematic vessel based survey in December 2004 (survey effort=89hours and 770km), February 2005 (survey effort=1.45hours and 17km) and March 2005 (survey effort=11.42hours and 42km)

Date	Latitude	Longitude	Proximity to shore (km)	Depth (m)	Coastal District (Region)	Species	School size	Behavior
9/12/2004	19.83155°	86.09797°	3.20	16.90	Puri	*N.phocaenoides*	3 to 4	Travelling
15/12/2004	20.52058°	86.84663°	4.60	11.40	Kendrapara	*N.phocaenoides*	2 to 3	Travelling
29/3/2005	19.96656°	86.35943°	0.45	7.40	Puri - Devi River	*S.chinensis*	5 to 7	Feeding
13/2/2005	20.7117°	87.17048°	9.00	9.30	Kendrapara-Gahirmatha	*S.chinensis*	3 to 4	Travelling
8/12/2004	20.08134°	86.46914°	0.58	8.80	Jagatsingpur	*S.chinensis*	20	Socialising in breaking waves
15/12/2004	20.7117°	87.17048°	7.40	8.30	Kendrapara-Gahirmatha	*S.chinensis*	50 to 70	Socialising
18/12/2004	21.02646°	87.09634°	20.30	20.00	Bhadrak	*Tursiops aduncus*	5 to 7	Socialising. Traveling
10/12/2004	19.72005°	85.73129°	4.10	21.60	Puri- just outside Chilika	*S.longirostris*	30 to 40	Travelling Bow riding

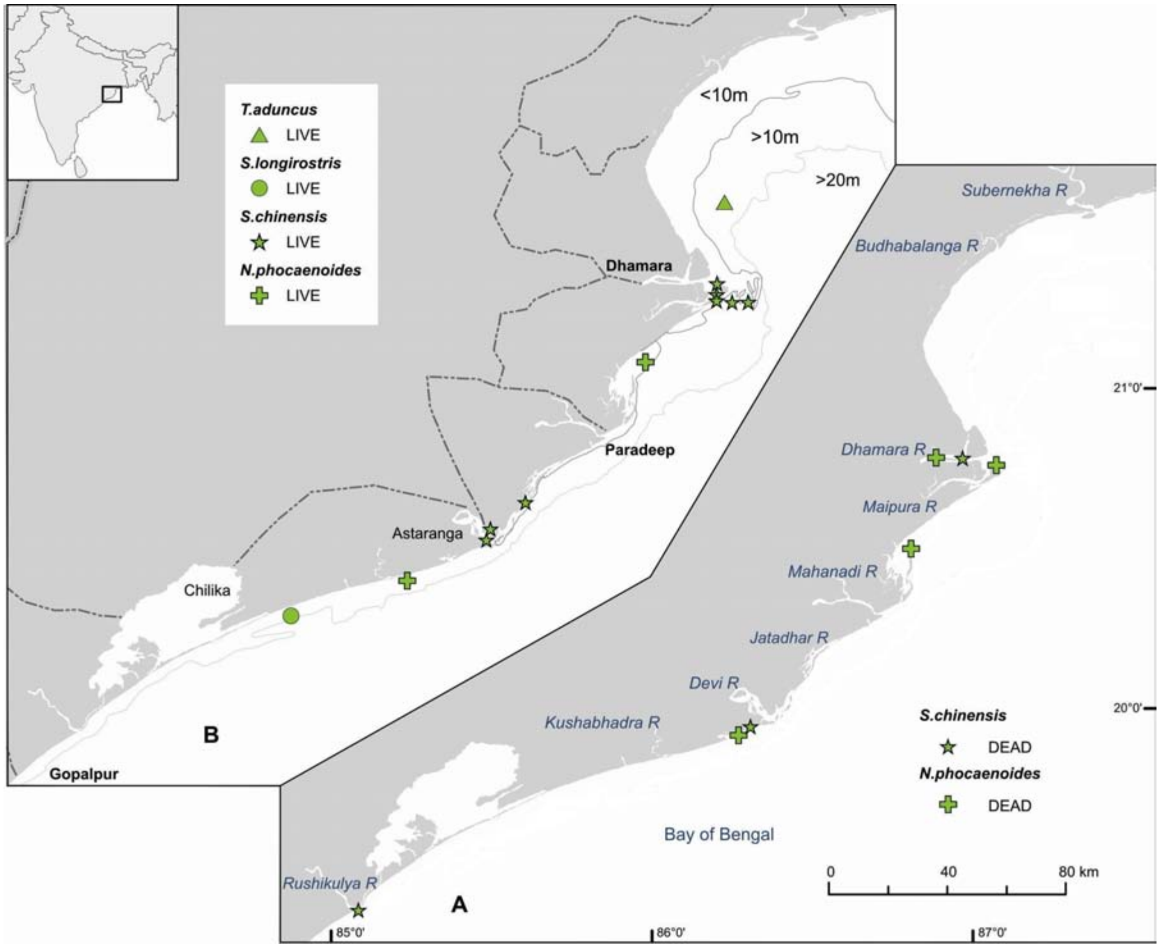


Figure 5.3. The coast of Orissa showing A) locations from where carcasses have been salvaged along the coast and B) species sighted during the boat based coastal survey.

5.4. Discussion

Five species of marine mammals were sighted during the coastal survey. Irrawaddy dolphins were not sighted. Our results suggest that Irrawaddy dolphins are not continuously distributed along the coast of Orissa. The species tends to be found in isolated pockets through out its range and the population in Chilika is probably one such population.

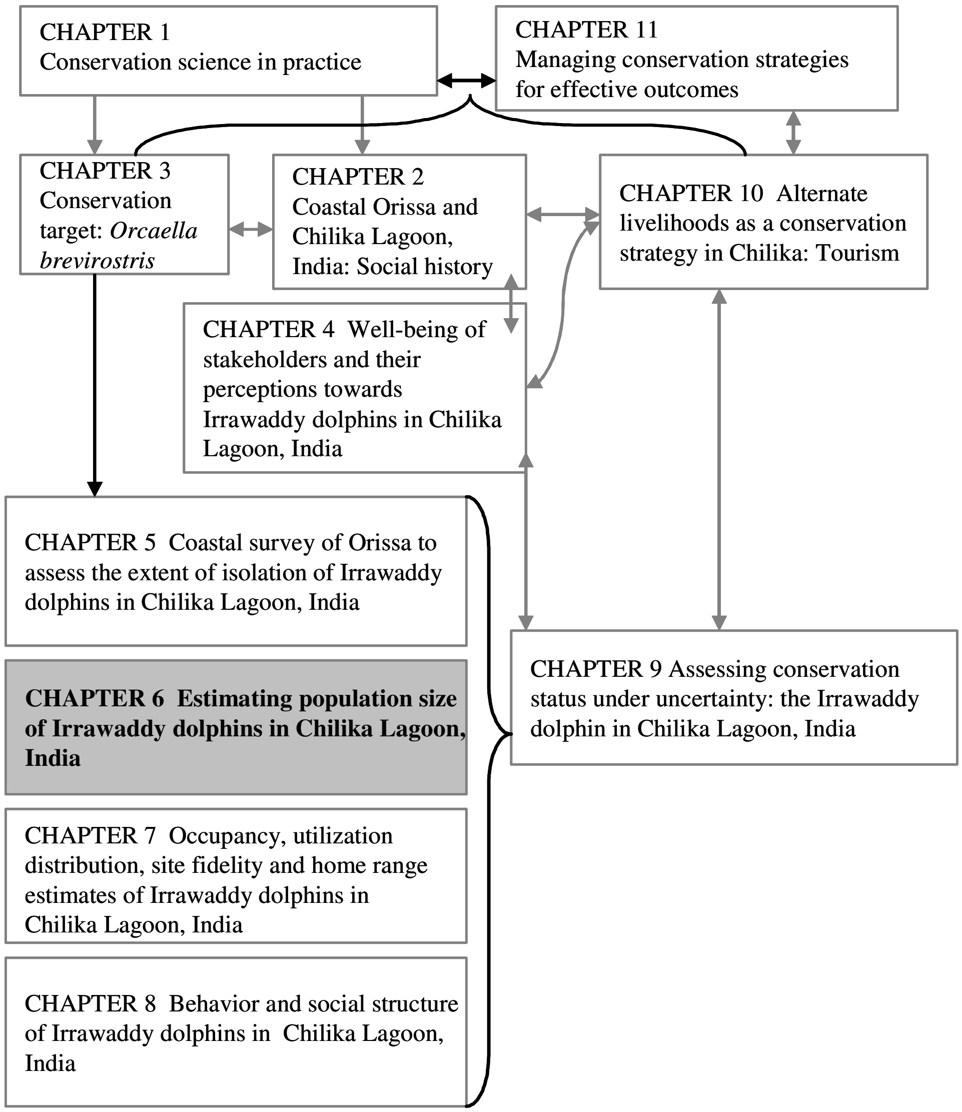
Based on carcass information, Irrawaddy dolphins could be present in other regions along the coast. Gahirmatha Sanctuary at the mouth of the Brahmani River is one such region, due to its shallow and mangrove rich habitat. Our vessel survey covered only the outer coastal stretch of this region, where *N. phocaenoides* and *S. chinensis* were sighted. Carcasses of these two species have also been recorded from this region, but the inner waterways of the mangrove forests were not included in the survey. A concentrated survey effort in the entire Gahirmatha region is needed to give a clearer picture of the presence/absence of Irrawaddy dolphins here.

The coast of Baleshwar in north Orissa (Figure 5.2) is shallow and muddy connects directly to the mangrove-rich coastline of West Bengal and Bangladesh. The confirmed presence of a large population of Irrawaddy dolphins in the Sunderbans and along the coast of Bangladesh (Smith et al. 2005; Smith et al. 2006) suggests that the probability of Irrawaddy dolphins along the coast of West Bengal are high. Dedicated line transect surveys of the Sunderbans and coast of West Bengal would complement the population assessment in neighboring Bangladesh and provide a more robust analyses of the status of Irrawaddy dolphins in the Indian sub-continent.

5.5. Chapter Summary

- The coastal survey of Orissa for Irrawaddy dolphins consisted of 89 hours and 770km of search effort.
- Five species of marine mammals were sighted along the coast of Orissa in waters up to 20m deep, but no Irrawaddy dolphins were sighted. This result suggests that the population of Irrawaddy dolphins in Chilika is isolated.
- The absence of recent Irrawaddy dolphin carcasses along the coast also supports the contention that the population in Chilika is geographically isolated.
- The nearby regions most likely to harbour other populations of Irrawaddy dolphins are Gahirmatha Sanctuary in Kendrapara and the region between West Bengal and Baleshwar. Habitat types preferred by Irrawaddy dolphins (muddy, shallow waters, and confluences where fresh and sea water mix) are found in these regions.
- Data from this chapter along with the traditional knowledge of dolphin presence in Chilika discussed in Chapter 4 are used to assess the status of Irrawaddy dolphins in Chilika Lagoon in Chapter 9.

6 ESTIMATING THE POPULATION SIZE OF IRRAWADDY DOLPHINS IN CHILIKA LAGOON, INDIA



One of the fundamental requirements to inform the conservation of a species or a population is to obtain a robust estimate of population size so that future trends can be modeled inclusive of uncertainty and an index of vulnerability can be assigned to the species. As outlined in Chapter 5, the Irrawaddy dolphin population in Chilika Lagoon appears geographically isolated. In this chapter, I estimate the abundance of Irrawaddy dolphins in Chilika lagoon using photo-identification based Mark-Recapture (M-R) methods. I review the assumptions of Mark-

Recapture models and test closed population models over short time frames to approximate demographic closure and open population models over longer time frames. Using the Coefficient of Variation estimates from this Mark-Recapture study, I predict the number of years it would take to detect a decrease in population size with high power (if the rate of decrease is 5% per annum) and use the Potential Biological Removal technique to estimate the level of sustainable anthropogenic mortality.

6.1. Introduction

The IUCN Red List criteria (IUCN 2006a) require estimates of absolute abundance as an index of the vulnerability of species or populations as the basis for detecting trends. Accurate estimates of population size are also necessary to assess the impacts of different threats on a population, including human-related mortality, using modeling techniques such as Trend Analysis (Thompson et al. 2000, Gerrodette 1987), Population Viability Analysis (Shaffer 1990, Possingham et al. 1993; McCarthy et al. 2003) and Potential Biological Removal (Wade 1998; Keith et al. 2004).

The probability of detecting a trend depends on the statistical power of the sampling protocol which in turn depends on other factors such as: the length of the monitoring period, the rate of change in the population, the frequency of surveys and the precision (Coefficient of Variation or CV) of the population estimate, which is typically negatively correlated with the size of the population (Gerrodette 1987). In the case of cetaceans, population trends are very difficult to estimate because: (1) detection probability is affected by observer and sea state variables and obtaining precise estimates of absolute abundance or robust and precise indices of relative abundance is difficult, and (2) because increases in population size are typically slow due to cetacean life histories. There are no similar constraints on population decline, but in the absence of catastrophes, most declines are also likely to be relatively slow. Thus trends in small populations become almost impossible to detect as animals become increasingly rare.

Estimating the absolute abundance of wild populations is very challenging, often requiring the researcher to weigh the risk of the uncertainties associated with biased estimates against the realities of resource capacity, logistics and weather conditions. As discussed in Chapter 3, two main methods are now used for cetaceans: Distance Sampling (Hammond et al. 2002; Buckland, 1993; Dawson, 2008) and Mark-Recapture methods (Hammond et al. 2002; Pollock, 2006 ; Bradshaw, 2007). Both methods have advantages and disadvantages and the most suitable method depends on the spatial scale of the survey areas, the size and spatial arrangement of the population and whether or not it bears natural marks (Table 3.1 Chapter 3).

Some cetacean biologists still use Direct Counts to provide estimates of relative abundance as shown in Chapter 3 (Table 3.1). This approach generally aims to develop indices that reflect spatial patterns of abundance or temporal trends in population size. Unfortunately, such methods do not usually yield robust indices or accurate population estimates because the counts cannot be adjusted for imperfect detection of animals by the observers. Another difficulty with Direct Count techniques is that they produce a single estimate of population size for each survey without any concurrent measurement of error, which increases the challenge of modeling trends and optimizing a monitoring program. There are methods for dealing with such problems but only when a long-time series based on a standard protocol is available. Consequently, marine mammal scientists have consistently cautioned against using Direct Count data for trend analyses because of the problems with varying detection probability.

Irrawaddy dolphins mostly occur in turbid waters and often reside in narrow, irregularly shaped bodies of water that are difficult to survey because the highly clumped distributions of the animals make it difficult to obtain a suitable sample to estimate density. Irrawaddy dolphins also show cryptic surfacing behavior (Stacey & Arnold 1999) making them difficult research subjects.

Prior to my study, the population of Irrawaddy dolphins in Chilika was monitored using Direct Counts (Table 3.1 Chapter 3) (Pattnaik et al. 2007). The mean number of dolphins recorded during monthly surveys from 2003-2005 was 85 individuals, (SD =18.5, Range = 62-98). In addition to the problems with Direct Counts outlined above, Chilika is a relatively small virtually enclosed body of water (Chapter 2). There is a high risk of double counting individuals resulting from movement of animals during a single survey on the same day. To reduce the risk of double counting, in February/March each year from 2005-2008 inclusive, observers in18 boats were employed simultaneously obtained synoptic counts of population size with the following results: 111 dolphins (2005); 131 (2006), 135 (2007) (CDA 2007),138 (2008) and 146 (2009)(IANS 2008, 2009). The synoptic counts suggest that the population is increasing at 15-20% per year, a figure that seems highly unlikely given the demography typical of dolphin populations (R_{max} ~0.04; Wade 1998) and the concurrent unnatural mortality estimates of 7% p.a estimated for 2002-2006 (Pattnaik et al. 2007).

Direct Counts, including synoptic Direct Counts produce a single number for population size without any concurrent measurement of error. However, a robust estimate or index of population size in Chilika could remove noise in the data by correcting for the heterogeneity in detection probability caused by availability and perception biases (Marsh & Sinclair 1989). Accurate estimates could then be used in modeling techniques such as Population Viability Analysis (Shaffer 1990)and Potential Biological Removal (Wade 1998).

My review of the literature (Table 3.1 in Chapter 3) demonstrated that Mark-Recapture techniques using photo identification of naturally marked animals consistently provide greater precision than direct counts or line-transect surveys for relatively small (< 250 animals) populations of Irrawaddy dolphins. It was important to use a method in Chilika that could help detect the changes in population size over time with minimal bias. In this chapter, I present the estimates of the total population size of dolphins in Chilika obtained from Mark-Recapture studies. I also use these estimates to predict the number of years required to detect a decrease in population size and to estimate the level of human caused mortality (by-catch) that is likely to be sustainable.

6.2. Methods

6.2.1. Study Area

As outlined in Chapter 2, Chilika Lagoon is a brackish-water lagoon/lake located in Orissa, India (19° 28'N - 19° 54'N and 85° 05'E – 85° 38'E; Figure 2.2 in Chapter 2). The Lagoon is separated from the Bay of Bengal by a spit which is ~1.5km wide and 60km long. An artificial mouth, 250m wide, was dredged in September 2000 to maintain the influx and circulation of salt water into the Lagoon (Ghosh et al. 2006). The Lagoon undergoes regular maintenance dredging to prevent silt collection in the Northern Sector and Outer Channel. Details of the study area are given in Chapter 2.

6.2.2. Survey Design

The dolphins in Chilika Lagoon were photographed using boat-based surveys between November 2004 and April 2005 (Year 1 of my study) and November 2005 to May 2006 (Year 2 of my study). The lagoon was divided into four survey regions: (1) Outer Channel, (2) Central Sector, (3) Southern Sector, and (4) Northern Sector (Figure 6.1). A long tailed boat (9HP) followed one of two routes at 9km/hr: (1) parallel transect lines, and (2) zig-zag transect lines (Figure 6.2). Both routes covered the Central, Southern and Outer Channel regions of the Lagoon only. The Northern Sector of the Lagoon is weed infested, covered with a high density of fixed fishing gear, and shallow making it very difficult for a boat to traverse along pre-defined transect lines. I also surveyed the navigable regions of the Northern Sector in 2004 and 2005. Dolphins were sighted only in a dredged channel in the Northern Sector, and thus only the dredged section of the Northern Sector was included in the surveys (Figure 6.1). The major justification for omitting most of the Northern Sector is that no dolphins have been seen in the Northern Sector of the lagoon during the direct count surveys (Table 3.1, Chapter 3) carried out by the Chilika Development Authority since 2000 (Pattnaik et al. 2007).

My search effort was constrained by weather conditions and most surveys took place between 06:00am-12:00pm and 15:00pm-17:00pm. A complete survey usually took seven days. If the entire track (Figure 6.2) was not surveyed as a result of unsuitable weather, the data were excluded from the Mark-Recapture population analysis. Every survey was designed to obtain equal coverage of the survey area. Transect lines were placed 1.5km apart and no data were collected on return legs to minimize the likelihood of double counting.

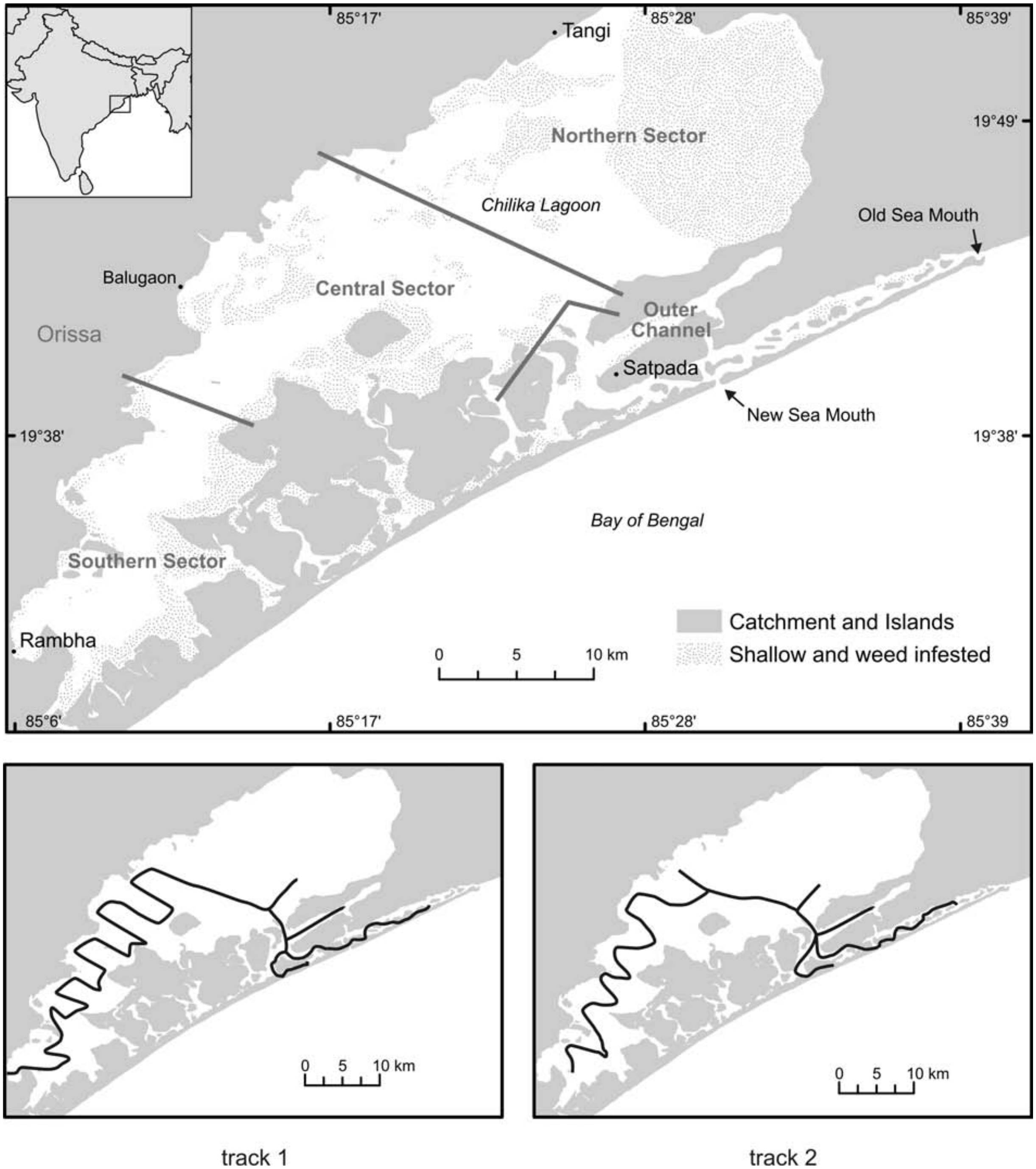


Figure 6.1. Chilika Lagoon, on the north-east coast of India showing the sectors used to design the vessel surveys (track 1 and track 2) for estimation of Irrawaddy dolphin abundance.

6.2.3. Data Collection

6.2.3.1. Approaching and Photographing Dolphins

When dolphins were sighted, they were approached at slow speed, to avoid disturbing them. This method also helped orient the observers and enabled them to photograph the dolphins from the best possible angle, i.e., perpendicular to the fin. When the vessel was within 100m of the dolphins, the engine was stopped and oars were used to get closer to the animals, thus increasing the likelihood that all animals would have an equal probability of being photographed. If the animals were traveling, the boat was kept parallel to them while continuing the photography.

The dorsal fins, flukes and backs of individuals were photographed digitally using a EOS 20D Canon digital camera with a 70-300mm Image Stabilizer Ultrasonic zoom lens. I tried to photograph both the left and right sides of each fin and to avoid backlit pictures whenever possible. I took a blank shot every time I finished photographing one group of dolphins to separate sightings within days.

6.2.3.2. Defining a Group

A group was defined as every dolphin within 10m of any other member of the group (Smolker et al. 1992) and displaying similar behavior. The main categories of behavior were recorded as: (1) affiliative or social, (2) feeding or foraging, (3) milling, (4) traveling and (5) resting as explained in Chapter 8 (See Section 8.2.3 and Appendix B)

6.3.2.3. Group Data Collection

While the primary observer photographed individuals, secondary observers counted the number of animals in the group, noted their GPS location and behavior and collected environmental data. The observers remained with a group until all animals were photographed or until they had moved away and did not resurface for at least ten minutes. It was not always possible to obtain information on group composition given the time available and the low clarity of the water. The presence of calves and juveniles was noted. Adults or sub-adults (distinguished by relative size) closely accompanying calves and juveniles were assumed to be female dolphins. The data on the sex of individual dolphins have not been used in the Mark-Recapture analysis due to small sample size, but have been presented in home range estimates in Chapter 7.

6.3.2.4 Photograph Cataloging and Rating

Each day's photographs were rated on the basis of clarity and angle as poor, medium, good and excellent. Only good and excellent pictures of dorsal fins were included in the analysis. Photographs from each day were placed in folders labeled by sighting number for that day, i.e each day consisted of Sighting 1 to Sighting x, depending on the number of groups encountered. I catalogued individuals based on the position of cuts, nicks and nips on the dorsal fin. Some individuals had secondary marks on the back of the dorsal fin (Appendix A). Such marks were included as identification keys in combination with the dorsal fin. One animal was uniquely catalogued on the basis of a scar on the face but no marks on the fin.

6.2.4. Model Selection and Data Analysis

The encounter history was created from a complete survey from each month of survey effort, giving a total of 12 occasions over the whole study period. The number of times any given individual was sighted (Figure 6.3) and individual resightings for each month were plotted (Figure 6.4) to make a discovery curve (Figure 6.5). The encounter histories were then fitted into appropriate Mark-Recapture models to estimate population parameters.

The main requirements of any mark-recapture study are that :1) animals have permanent identifiable marks which are recorded correctly, 2) sampling events are independent, 3) animal detections are independent, and 4) the mark-rate is quantified (Williams et al. 1993; Borchers et al. 2002). Even though my sampling protocol was designed to capture all animals, the assumption of equal catchability of all individuals in a group was probably violated. This problem exists in all cetacean Mark-Recapture studies because of inherent differences in behaviour of the individuals with respect to boat avoidance or environmental conditions (Wilson et al. 1999). I list the assumptions of Mark-Recapture studies and the likelihood that I violated them in Table 6.1.

Mark-Recapture probability models generate a likelihood function for catchability for given encounter histories. Likelihood functions for estimating abundance are characterized by differences in catchability at individual and group levels and within and between sampling, i.e. heterogeneity in individuals, survey time and environment. Neglecting heterogeneity can result in negatively-biased abundance estimates. Various estimators have been developed to capture as much heterogeneity as possible, given that the assumptions of the proposed model and estimator are not violated (Table 6.1). Depending on the source of heterogeneity, capture probability can be affected by the behavioural response of the dolphin to the presence of the research vessel M_b, time/season of sighting M_t and inherent heterogeneity M_h . Four simple models can be fitted to the data:

M_o, where capture probability is constant- unaffected by behavioural response, time or individual heterogeneity

M_h, where capture probability is affected by individual heterogeneity only

M_b, where capture probability is affected by behaviour only

M_t, where capture probability is affected by time only

I also considered more complex models such as M_{bh}, M_{th}, M_{tb} and M_{tbh} (Table 6.2).

I used both Open and Closed population models to estimate population size for three reasons: 1) to allow for a range of errors in population size estimation, 2) to compare results of different generic models, and 3) to work within the constraints of the available data to generate the best possible estimate.

6.2.4.1. Closed Population Estimation

Given the period covered by the data set, the known recorded dolphin mortalities and the apparent geographical isolation of the population, Closed population models were used for encounter histories as follows: a) over three months (February 2006 - April 2006), a period during which only one animal was recorded dead; and b) over six months (November 2005-April 2006), a period during which three animals were recorded dead. To minimize the effects of violating the assumption of demographic closure (births and deaths), short sampling periods were used to test for the closed population models. The encounter history was tested for 'closure' within CAPTURE and then tested to fit an appropriate model to estimate population of marked animals. CAPTURE used Goodness-of-Fit and between-model fit tests to compare different population models that could have produced the observed capture histories under closed conditions. Chi-square testing along with an overall discriminant function test was used to select the most appropriate model in each case. The null hypothesis was the more restrictive model (fewer parameters) and the alternate hypothesis was the more general model. The overall model selection function (Otis et al. 1978; Rexstad & Burnham 1991) gave scores of 0-1 to possible models, with higher scores indicating models which gave a better fit to the capture history. Models with scores >0.75 could be appropriate models. I used the highest scoring model and the next highest scoring model, with appropriate estimators to estimate the size of the population of marked animals $(\hat{N})$ for data from both sampling periods.

6.2.4.2. Open Population Estimation

The discovery curve (Figure 6.5) suggested that the population in Chilika was geographically closed during our study period. However, high known mortality figures and unknown calving rates violated the assumption of demographic closure. I used Jolly-Seber (JS) models to fit the encounter history data separately for two periods: (1) November 2005-April 2006, and (2) by pooling data from both November 2004-April 2005 and Nov 2005-April 2006 separated by a six month interval (May 2005-October 2006). The parameters of the Jolly-Seber models were estimated via maximum likelihood estimation, using POPAN capabilities in MARK 4.3 (White 2007). Both general and constrained models were tested using POPAN in Program Mark. Restrictions to a model can result in more precise estimates (Pollock et al. 1990) and models with and without time dependency were tested to fit the data. The model with the lowest Akaike Information Criterion (AIC) was chosen as the appropriate model. The lower the AIC, the better the model is supported by the data (Burnham & Anderson 1998; Williams 2002). I used Cormack-Jolly-Seber (CJS) models in MARK to estimate apparent survival probabilities for each of the two encounter histories.

Table 6.1. The list of assumptions involved in Mark-Recapture models used for the estimation of population size of Irrawaddy dolphins in Chilika, India and the methods used to avoid violating these assumptions while designing surveys and analyzing data

Assumption	**Bias from violation**	**Validation**	**Potential for violation**
Mark Recognition: marked animal is recognized if recaptured	Over-estimate of abundance	1. Analysis was restricted to good and excellent quality pictures 2. Animals with subtle marks were not included in the analysis 3. Additional marks like cuts, scars, shape of fin and pigmentation were also considered 4. Only one experienced person (DS) was responsible for cataloging the individuals to maintain consistency 5. The fins were segregated on the basis of location of mark on the fin, then on type of mark which were then connected to shape and additional marks.	Unlikely
Mark Loss: marks are not lost or do not change for the duration of the study period	Over-estimate of abundance	1. Combinations of nicks, cuts, notches, scars were used to ensure that the marks were long lasting 2. Study period was relatively short for marks to change substantially	Unlikely
Behavioral responses: Marking does not effect subsequent recaptures or survival	Trap shy: over estimate of abundance Trap happy: under estimate of abundance	1. Special care was taken to turn off the engine or maintain it in neutral before approaching the animals so as not to disturb the animals 2. I used the jackknife estimator by Pollock and Otto (1983) to model individual capture probability that varied due to behavior and inherent heterogeneity. The estimator works well for fewer than 10 marking periods in closed population models. This estimator can produce slightly negatively biased results.	Low
Geographical closure (In the case of closed models) N is constant and does not change over the study period	Inaccurate measure of actual animals using the lagoon when emigration, immigration, death and birth occur	1.Coast survey (Chapter 5) and interview surveys (Chapter 4) suggest that Irrawaddy dolphins stay in the lagoon throughout the year 2. Discovery curve suggests that the dolphins were in the lagoon throughout the study period	Unlikely
Permanent Emigration (In the case of open models)	Inaccurate estimate could lead to over estimate if animals are not modeled to leave when actually they do.	In our study emigration was taken as the equivalent of mortality	Unlikely
Homogenous capture probabilities: probability of capture for each animal during every event is equal	Under estimate of abundance	1. I used the moment estimator (closed models) with average capture probabilities by Chao (1988) for data that fit Mh 2. Average capture probability is > 0.5	Likely due to individual differences
Homogenous survival probabilities (Open models)	Under estimate of abundance	1. Average capture probability is > 0.5 and average survival capture probability is > 0.9	Unlikely

Table 6.2. Summary of the different models used to fit mark-recapture encounter histories based on closed population models by Otis et al. (1978) where 0 stands for the absence and 1 for the presence for each source of variability. P_{ij} = Probablity of capture of individual i…..x on occasion j….y. e.g. When there is no source of heterogeneity, the probability of recapture of all individuals over all occasions would be constant P. When capture probability is influenced by behavioral changes, the probability of recapture would be C for subsequent captures, and if this behavior varied over time and individual behavior, then the individual capture probabilities would be unique C_{ij} at subsequent captures.

Model	**Capture probablities**	**Source of variability**		
		Heterogeneity	**Temporal**	**Behavioral**
M_o	Constant P_{ij}=P	0	0	0
M_t	Varies with time P_{ij}=Pj	0	1	0
M_b	Varies with individuals P_{ij}=C	0	0	1
M_h	Varies with individual $P_{ij}=P_j$	1	0	0
M_{tb}	Varies with time and individuals $P_{ij}=C_j$	0	1	1
M_{bh}	Varies with individuals $P_{ij}=C_i$	1	0	0
M_{th}	Varies with time and individuals $P_{ij}=P_{ij}$	1	1	0
M_{tbh}	Varies with time and individuals $P_{ij}=C_{ij}$	1	1	1

6.2.4.3. Total Number of Marked Animals and Mark Rate

The abundance estimates ($\hat{N}$) obtained from the open and closed population models did not include unmarked individuals. To obtain a total population size including unmarked individuals, $\hat{\theta}$, the proportion of identifiable individuals for each analysis period was calculated as the ratio of the total number of good and excellent pictures for that period to the number of identifiable fins (Williams et al. 1993; Wilson et al. 1999).

6.2.4.4. Total Population Size

Total Population size was estimated as

$$\hat{N}_{total} = \frac{\hat{N}}{\hat{\theta}} \qquad (1)$$

where $\hat{N}_{total}$ is the estimated total population size, $\hat{N}$ is the mark-recapture estimate of the number of animals with identifiable marks, and $\hat{\theta}$ is the estimated proportion of animals with identified marks in the population. The variance of the abundance estimate was estimated using the Delta method (Wilson et al. 1999) where n is the number of animals from which $\hat{\theta}$ is calculated:

$$\mathrm{var}\left(\hat{N}_{total}\right) = \hat{N}^2{}_{total}\left(\frac{\mathrm{var}\left(\hat{N}\right)}{\hat{N}^2} + \frac{1-\hat{\theta}}{n\hat{\theta}}\right) \qquad (2)$$

6.2.5. Power Analysis

I used Program TRENDS (Gerrodette 1993) to calculate the number of years it would take to detect a change in population size at the four different levels of precision (CV=0.07, 0.08, 0.09, 0.25) obtained from the Mark-Recapture analysis. The computation in TRENDS depends on the relationships between five parameters: (1) *n*, the minimum number of sampling events/years; (2) *r*, the minimum rate of change between sampling events/years that can be detected; (3) *CV*, the maximum coefficient of variation, a measure of precision/error of estimates required to detect trends; (4) *α*, the probability of Type I error; (5) *β*, the probability of Type II error. The computations allow any one of the above parameters to be estimated if the other four are specified.

Program TRENDS requires the user to specify several assumptions. I assumed that: (1) the population was changing exponentially as most animal populations change as fractions per unit time; (2) the coefficient of variation is proportional to the square root of abundance as for single Mark-Recapture abundance estimates (Gerrodette 1993); and (3) the trends to be one sided (declining at alpha=0.05), and (4) the z distribution was appropriate. Using these assumptions and the estimated Coefficient of Variation values, I estimated the number of years it would take to detect a decrease in population size, for a population declining at 1-20% per year (one tailed test).

6.2.6. Potential Biological Removal

I used the Potential Biological Removal technique (Wade 1998) to estimate the maximum number of mortalities, excluding natural mortalities, which would enable the population to reach or maintain its optimum sustainable population. Based on simulation studies, populations with mortalities equal to or less than the Potential Biological Removal will exhibit two features: (1) that populations starting at the Maximum Net Productivity Level (MNPL) will remain at the same level or above after 20 years, and (2) that populations starting at 30% of carrying capacity will recover to the Maximum Net Productivity Level after 100 years. The Potential Biological Removal value is calculated as:

$$PBR = N_{\min} \, 0.5 R_{\max} \; F_R \qquad (3)$$

where $N_{\min}$ = the minimum population estimate of the stock

$0.5\,R_{\max}$ = half the maximum theoretical net productivity rate

F_R = a Recovery Factor of 0.1 and 1

Life history parameters such as age of first reproduction, mean calving intervals and maximum life span are unknown for the population of dolphins in Chilika (Chapter 3). I used the conservative value of 0.04 for R_{max} based on growth rates of 4%-6 % (Wade 1998) exhibited by odontocetes with similar life histories. In calculating the mortality limit, I use a conservative surrogate of half the growth rate so that 0.5 R_{max} is always less than the net productivity or carrying capacity of the population. Considering the estimates of unnatural mortality, I chose a positive yet moderate Recovery Factor of 0.5 for this population which can help compensate for biases in N_{min} and R_{max} estimations.

6.3. Results

I spent 229 hours and covered 1428 km of search effort on photo-identification surveys between November 2004 and April 2006. I found that the group encounter rates were independent of survey design (parallel and zig zag), but decreased significantly in the month of January, presumably as a result of the rough weather conditions. The group encounter rate in the Outer Channel (0.78/hr ±0.28) was much higher than in the Central and Southern Sectors (0.12/hr ±0.5).

I obtained 441 identifications of 80 Irrawaddy dolphins (Figure 6.2, 6.3 and 6.4). All identified individuals were adults or sub-adults; calves and juveniles were unmarked and could not be identified (Appendix C shows the different age group classifications). The mark rate of individuals in the population was high and varied from 0.70 to 0.75 depending on the period of analysis (Table 6.3). Eighty individual dolphins were sighted 1-11 times over the 12 surveys; 69% of the individuals were sighted more than five times over the study period. I plotted these individuals over the survey period to produce the discovery curve (Figure 6.3). The number of new individuals identified increased in the beginning of the study as expected showing that unidentified marked individuals were still present in the population and decreased in the latter half of the second year of the study.

Population closure could not be proved using Closure tests in CAPTURE. Closure tests are very sensitive to heterogeneity in capture probabilities and did not give positive results for my encounter history. But the cumulative number of identifiable individuals plateaued (Figure 6.3) by the end of the study period, suggesting that the population was geographically closed for the duration of the study, a conclusion that agreed with the results of the coastal survey described in Chapter 5.

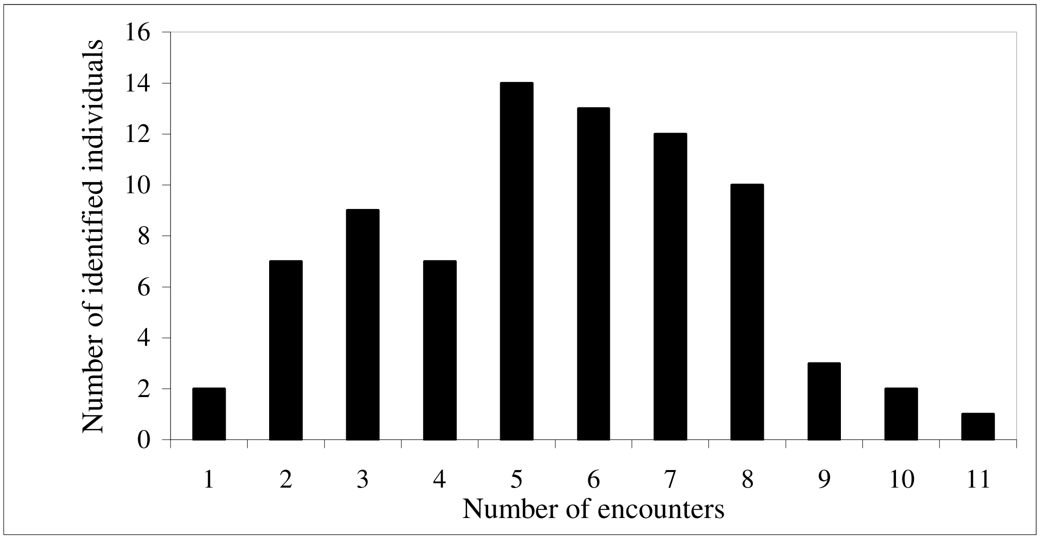


Figure 6.2. The frequency of encounters for identified Irrawaddy dolphins in Chilika over 12 surveys between Nov 2004 and April 2006 showing that more than 60% of the identified animals were sighted five times or more in the lagoon during the study period.

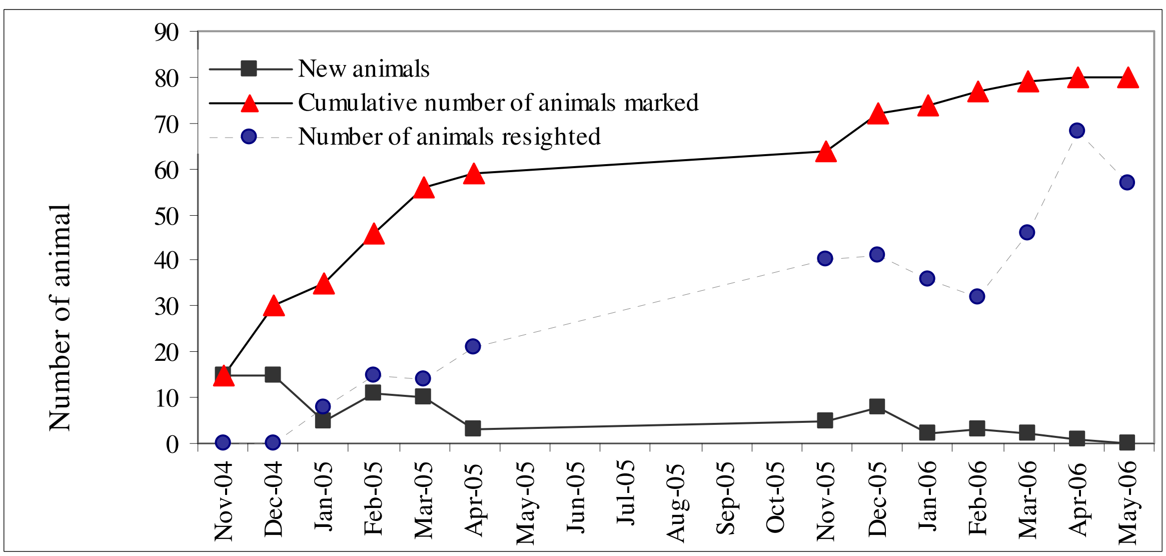


Figure 6.3. Discovery curve and cumulative number of individual Irrawaddy dolphins photo-identified between November 2004 and May 2006 in Chilika.

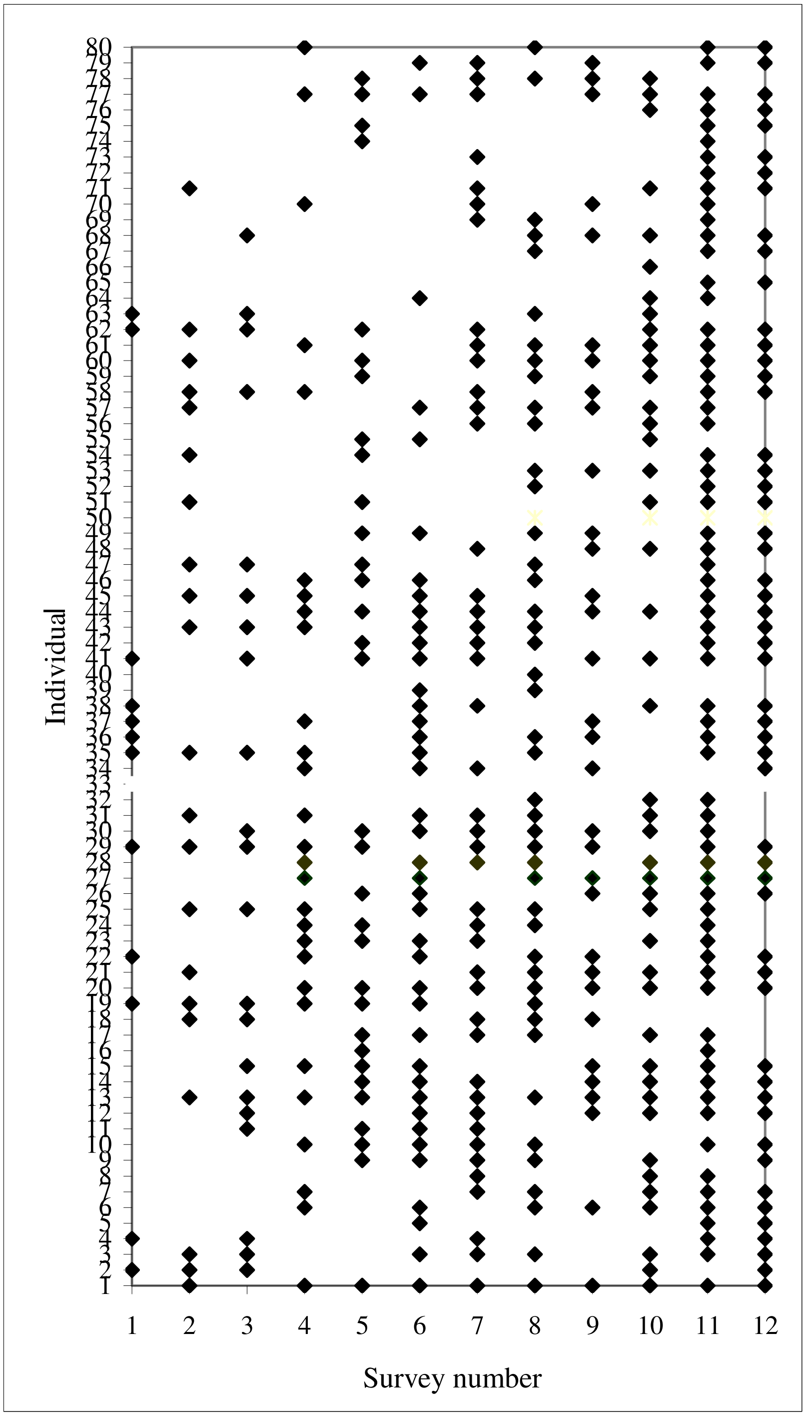


Figure 6.4. Scatter plot for individual recaptures of Irrawaddy dolphins over surveys 1 to 12, in Chilika. This figure shows that the identified individuals were consistently seen within the Lagoon over the study period, suggesting that the population is geographically isolated.

6.3.1. Population Size

All the closed and open population models tested estimated the size of the population of Irrawaddy dolphins occupying Chilika lagoon to be less than 150 animals (Table 6.3). Closed population models over three month periods from Year 2, estimated a range of abundance values ranging from 95 (SE=8.9, CV=0.09, $\hat{N}$ =70); to 140 (SE=34.4, CV=0.25, $\hat{N}$ = 98) (see Table 6.3 for details of periods within Year 1 and 2). The population estimate obtained using closed models over a 6 months from Year 2 was 111 (SE=8.6, CV=0.08, $\hat{N}$ =83). The open population models estimated a total abundance of 109 (SE=8.1, CV=0.07, $\hat{N}$ =82) over 6 months from Year 2, and an estimate of 112 (SE=8.5, CV=0.07, $\hat{N}$ = 84) from pooled data of two, six month periods from both years. The estimated survival probability of marked animals over pooled data of two, six month periods from both years was 0.98 (SE=0.06) though this is a preliminary estimate.

Table 6.3. Estimates of population size for Irrawaddy dolphins from Chilika Lagoon, India using Closed and Open Mark-Recapture methods over different time periods[4]

Closed population models (CAPTURE)										
Season	**Model**	***n***		$\hat{N}$	**SE**	**95 % CI**	$\hat{\theta}$ **(SE)**	$\hat{N}_{total}$	**SE**	**CV**
Nov 05-Apr 06	M (bh)	80		83	2.8	81-94	0. 75 (0.02)	111	8.6	0.08
Nov 05-Jan 06	M(o)	63		70	5.7	66-81	0.75 (0.03)	95	8.9	0.09
Feb 06-Apr 06	M(o)	75		79	2.6	77-88	0.74 (0.02)	107	8.1	0.08
Jan 06-Mar 06	M(b) Zippin	67		98	22.8	76-179	0.70 (0.03)	140	30.3	0.25
Open population models (POPAN)										
Season	**Model # parameters**	**n**	**p**	$\hat{N}$	**SE**	**95 % CI**	$\hat{\theta}$ **(SE)**	$\hat{N}_{total}$	**SE**	**CV**
Nov 05-Apr 06	φ(.) p(t) λ (.) N(.) 9	80	0.60	82	2	80-90	0. 75 (0.02)	109	8.1	0.07
Nov 04-Apr 05 Nov 05-Apr 06	φ(t) p(.) λ (.) N(t) 14	80	0.48	84 φ= 0.98	2.4	81-92	0.75 (0.02)	112	8.5	0.07

[4] M(o)=capture probability not affected by any factors, M(b)= capture probability affected only by individual behavior; M(bh)= capture probability affected by individual heterogeneity and behaviour, φ (.)= survival probability constant and φ (t)= survival changes with time; p(.)=capture probability constant or p (t) changes with time given animal available for capture; λ(.)=probability of entry into the population for this occasion constant; n= number of individuals marked; $\hat{N}$ = estimated population of marked animals = proportion of animals marked/id; $\hat{N}_{total}$ = estimated absolute abundance of dolphins in Chilika, φ=estimated survival probability over two years.

6.3.2. Power Analysis

The power analysis confirmed that it would take many years to detect a trend in the small population of Irrawaddy dolphins in Chilika Lagoon. I estimated that if the rate of decrease were constant at 5% per year, then at the highest level of precision CV=0.07, it will take seven years to detect a population change with high precision. Only if the rate of decrease is as high as 20% per year, could the decrease be detected within three years (Table 6.4). In all these cases, the population will have fallen to less than 100 animals by the time a rate of change of 5% is detected (Table 6.4) (Figure 6.5).

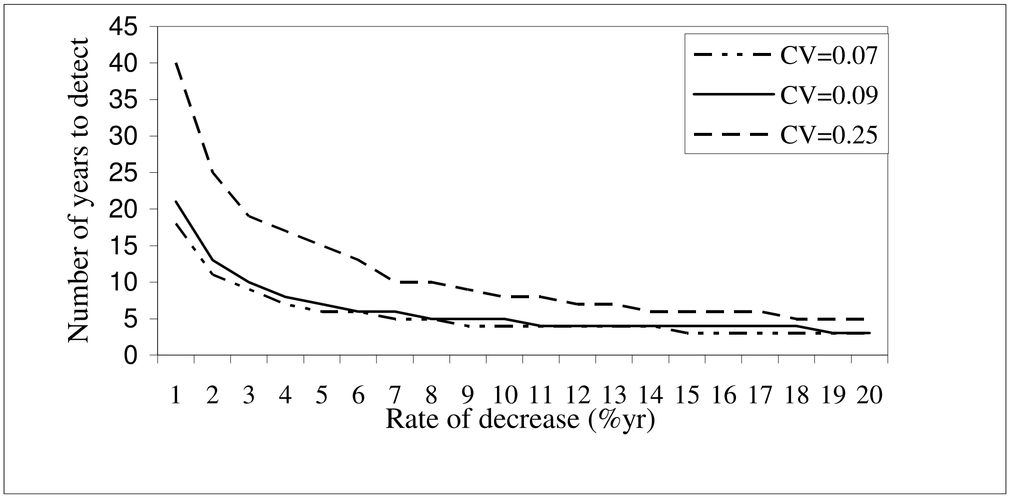


Figure 6.3. Minimum number of years required to detect a decrease in population size with high power at standard rates of decrease/yr for three levels of precision using TRENDS software (Gerrodette 1993). The probability of both Type I and Type II errors was 0.05.

6.3.3. Potential Biological Removal

The population of dolphins in Chilika is not sustainable at the reported rates of anthropogenic mortality reported between 2002 and 2006. I calculated the minimum population estimate as the 20th percentile of a log normal distribution based on the absolute estimates of population size in Chilika as 88-114 animals with a Potential Biological Removal value of ≤1 animal per year (Table 6.5). Given the small size of the population and the recommended Recovery Factor of 0.1 for Critically Endangered populations (Chapter 9), the Potential Biological Removal is even lower at <1 animals per year.

Table 6.4. Effect of different annual rates of change on the number of years required to detect population trends in Irrawaddy dolphins with yearly survey intervals (t=1) with high power (95%). Data variability was specified at CV=0.07, 0.08, 0.16, 0.25 corresponding to the highest level of precision obtained for abundance estimates (see Table 1). The probability of both Type I and Type II errors was set at 0.05

Data type and analysis	Rate of decline (r) per year	Number of years to detect decrease	For a decreasing population [5] Total	
			% change at detection	resulting population size
CV=0.07 Population size: 112 t=1	0.05	6	-0.26	83
	0.1	4	-0.34	74
	0.15	3	-0.39	68
	0.2	3	-0.49	57
CV=0.08 Population size: 107 t=1	0.05	6	-0.30	78
	0.1	4	-0.34	74
	0.15	4	-0.48	58
	0.2	3	-0.49	57
CV=0.09 Population size: 95 t=1	0.05	7	-0.30	67
	0.1	5	-0.41	56
	0.15	4	-0.48	49
	0.2	3	-0.49	48
CV=0.25 Population size: 140 t=1	0.05	14	-0.54	64
	0.1	9	-0.57	60
	0.15	7	-0.62	53
	0.2	6	-0.67	46

Table 6.5. Estimates of the annual anthropogenic mortality (Potential Biological Removal) that would allow the recovery of the Irrawaddy dolphin population in Chilika Lagoon, India using the range of population estimates (N) and standard errors (SE) obtained from mark-recapture analysis and assuming the default values for maximum rate of increase for cetaceans (R_{max}) of 0.04 and Recovery Factor (RF) =0.5 for populations of unknown status (Wade 1998) and Recovery Factor = 0.1, the recommended value for a Critically Endangered species (See Chapter 9).

N	SE	CV	Nmin	PBR (R=0.5)	PBR (R=0.1)
112	8.8	0.07	105	1.05	0.18
109	8.1	0.07	102	1.02	0.23
95	8.9	0.09	88	0.88	0.20
140	34.4	0.24	114	1.14	0.21
107	8.1	0.07	100	1.00	0.20

[5] $(1 - r)^{(t(n-1))}$ -1 Rate of decrease for exponential change

6.4. Discussion

This study confirms that the population of dolphins using Chilika is small. Estimates of population size range from a minimum of 95 (SE=±8.9) to a maximum of 140 (SE=±34.4) animals (Table 6.3). Both estimates are from three-month encounter histories that include the month of January, when the number of recaptures was lowest. Based on estimates that excluded January data, the population size was estimated to be around 107 (SE= ±8.1). A similar figure is obtained from Open population models of encounter histories from 6 months and 12 months.

Like other populations of Irrawaddy dolphins inhabiting riverine or lagoonal habitats, this population is also faced with a range of anthropogenic threats and the estimates of my study are a serious cause of concern for the long term survival of such a small population. In Chilika, Irrawaddy dolphins are threatened by entanglement in fishing nets, habitat degradation and fragmentation. My results confirm that more than 60% of the marked animals were sighted more than five times in the lagoon, showing that they used the lagoon through most of the study period. Moreover, the number of marked animals in the population plateaued by the end of my second field season (May 2006) suggesting that more than 80% of the identifiable individuals had been captured and more importantly that the population was geographically closed during the study period. Conservation strategies need to focus on improving the quality of the habitat and on mitigating mortalities from fishing nets for assuring the survival of the population.

Although I was not able to detect trends in population size, this result is not unexpected. The TRENDS analysis showed that declines are difficult to detect over short periods unless change is very high by which time it would be too late revive the population. By the time a 5% per annum decrease is detected a population of 112 animals will have reduced to 83 animals (Table 6.4). My conclusion about the status of the population differs from the increasing trend suggested by the synoptic counts, and indicates that the current monitoring protocol of Direct Counts should be revised to better reflect uncertainty.

Photo-identification is a challenge for elusive diving species, but has proved to be highly successful for the population of Irrawaddy dolphins in Chilika. My study has produced a catalogue of individuals for future use which I shall be making available on the internet for use by future researchers. The catalogue has also shown that encounter history from a three month period can give comparable estimates of population size to monitor trends over time. I suggest that owing to the small population size, long-lasting natural marks and enclosed nature of the study area photo-identification based Mark-Recapture methodology would be appropriate for future monitoring of the population based on my catalogue.

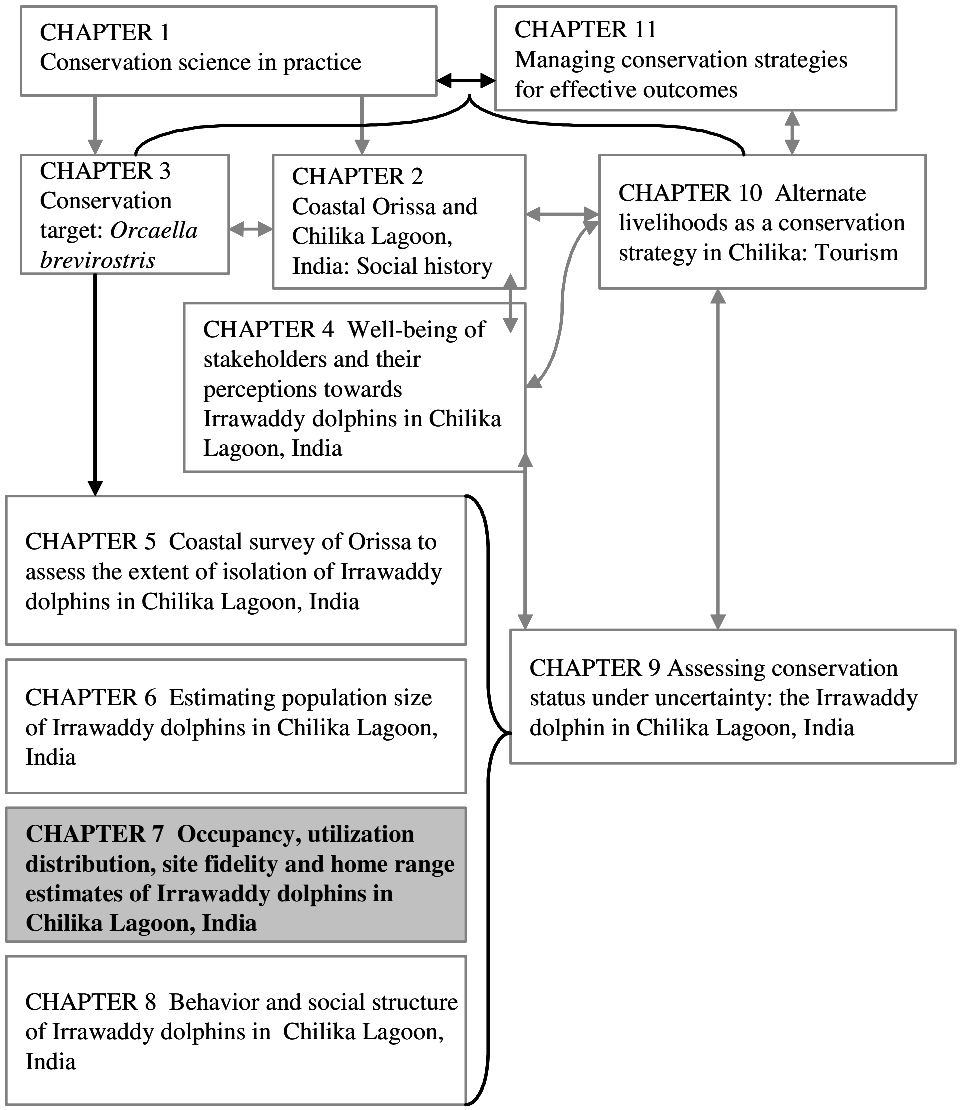
Five of the seven cetacean populations listed as 'Critically Endangered' by the IUCN are sub-populations of Irrawaddy dolphins (Chapter 3). All these subpopulations are small, isolated and live in human-dominated environments. There seems to be a pattern in the status and trends of these populations, most of which have fewer than 50 mature individuals. The population in Chilika has not been assessed separately by the IUCN. In Chapter 10 of this thesis, I carry out an assessment using IUCN Red List guidelines and the RAMAS software using the population estimates from this chapter. The low population numbers and the inability to detect trends before the population becomes too small, emphasizes that scientific proof of decrease should not be necessary to carry out conservation measures (Taylor et al. 2007b).

6.5. Chapter Summary

- Abundance estimates are important objectives of programs to design conservation strategies and also an important aspect of species ecology. Direct Count methods including synoptic counts do not provide uncertainty around estimates and generally cannot be used to detect trends in abundance.
- I used photo-identification data collected from Nov 04-Apr 05 and Nov 05-Apr 06 with Closed and Open Mark-Recapture models to provide abundance estimates of Irrawaddy dolphins in Chilika lagoon.
- I estimated the total population size of Irrawaddy dolphins in Chilika to be very small at 109 to112 individuals at CV=0.07; and 140 at CV=0.25, based on surveys from November 2004 to December 2006.

- The power analysis indicated that a 5% rate of decrease per year would take 7 years to detect; even a decline of 20% would take 3 years to detect using the same survey protocols, by which time a population of 112 animals will have reduced to 57 animals.
- I use the results from this chapter to assess the status of the population in Chilika using the IUCN Red List guidelines in Chapter 9.

7 OCCUPANCY, UTILIZATION DISTRIBUTION, SITE FIDELITY AND HOME RANGE ESTIMATES OF IRRAWADDY DOLPHINS IN CHILIKA LAGOON, INDIA



In this chapter, I assess the importance of habitat size and availability to Irrawaddy dolphins in Chilika Lagoon. Quantifying the relationship between an animal and its environment in terms of the amount of space used is fundamental to conservation ecology. I estimate the 'range' and relative use of space by Irrawaddy dolphins in Chilika Lagoon at the ‘group’ and ‘individual’ level. I estimate their Extent of Occurrence and Area of

Occupancy and identify two core and two representative areas used by dolphins in Chilika using ArcView 3.3 and kernel density estimation methods. I investigate if there is a relationship between group size, behavior and environmental parameters to identify possible ecological influences on group sizes and space use. I use the Local Convex Hull (LoCoH) method, based on five to ten closest neighbours, to map the movement corridor outside of the representative range which maintains habitat continuity. At the individual level, I use the sighting data for individuals from groups with more then eight independent locations to test site-fidelity and to estimate individual home range sizes.

7.1. Introduction

Patch extinctions can result from habitat loss and fragmentation and thus the question about whether animals will remain in a given habitat or leave for better grounds if their habitat becomes less suitable is important (Medina-Vogel et al. 2008).The relationship between animals and their environments is an important component of population ecology. Quantifying this relationship in terms of the amount of space used by animals is fundamental to conservation biology (Gaston 1991, 1994). Estimating home ranges and movements at the level of individual animals helps scientists and managers better understand the affinity between animals and their habitats, in terms of niche type and size and also contributes to theories of social structure and territories. Especially for populations and sub-populations that are isolated and small, an understanding of movement and occupancy over a broad range of temporal scales (weeks, months or years) can help answer questions about site fidelity (Linkie et al. 2007).

Space use is a major criterion in assessing the status of threatened species (IUCN 2006a). Comparing the 'geographic ranges' of different species helps us to understand their relative distribution across ecotypes. The definition of 'range' is influenced by spatial scale and derived from detection-nondetection data. Gaston (1991) provided two definitions of 'range' based on sample counts focusing on records from individual locations- the *Extent of Occurrence* and the *Area of Occupancy*. The Extent of Occurrence encloses an area containing all the individuals of the species. The Area of Occupancy is the actual 'cell' area used by the animals when a grid is superimposed on the area. The obvious difference between the two parameters is that the Extent of Occurrence may include cells containing no individuals of the species.

The IUCN adapted the definitions of ‘range’ to measure the size of the habitat of a species against threshold values (IUCN 2006a). The IUCN Red List thresholds were developed for global assessments, but are also applicable for regional and national level assessments (IUCN 2003). The IUCN guidelines are well suited for global or regional assessment of a species, or for fragmented populations which intermix such that the sum of smaller areas is used for the assessment. However, these guidelines may not be appropriate for local isolated populations that have limited habitat availability. Some species show a patchy distribution with little or no movement among sub-populations, indicating that the relevant spatial scale needs to be considered before assessing the conservation status of such sub-global populations. Using the occupancy definition of 'range' as defined by the IUCN Red Listing process (Criterion B and the associated thresholds for categorization) for assessing risk at the level of such a single population tends to produce a mismatch of spatial management scales. It is thus desirable to define the distribution of interest at the relevant scale (e.g., in this case at the scale of Chilika Lagoon), and then quantify this distribution (MacKenzie et al. 2006) to estimate Extent of Occurrence and Area of Occupancy.

I concluded that Irrawaddy dolphins in Chilika Lagoon are geographically isolated (Chapter 5), and the population is ≤140 individuals (Chapter 6). The physical conditions of the Lagoon are heterogeneous with shallow muddy regions, deep water channels, sea weed cover, islands and sand spits interspersed with obstructions from fixed fishing gear (Figure 2.1 in Chapter 2). Because of the recent history of weed infestation and shrinkage of the Lagoon (described in Chapter 2), conserving the dolphin population of Chilika requires an understanding of the quality and size of habitat available in relation to the area used by the dolphins. In this chapter I: (1) map the distribution of the groups of dolphins in the Lagoon, (2) estimate their Extent of Occurrence and Area of Occupancy, (3) study the Utilization Distribution of dolphins in the Lagoon, (4) examine the site fidelity of individual dolphins to preferred areas and, (5) estimate the home-ranges of individual dolphins.

7.2. Methods

7.2.1. Study Area

Details of Chilika Lagoon are described in Chapter 2.

7.2.2. Survey Design and Data Collection

Survey design

Boat based surveys were conducted in Chilika during the dry seasons of November 2004 to April 2005 and November 2005 to May 2006 (see Chapter 6). Search effort was constrained by weather conditions and most surveys took places between 06:00am-12:00pm and 15:00pm-17:00pm at Beaufort state ≤3. To avoid interdependence of data sets, transect lines were placed 1.5km apart and no data were collected on return legs. I was not able to survey in the wet seasons due to the strong winds and sea states of Beaufort >3, leaving a gap in the information about seasonal space use.

The Lagoon was divided into four survey regions: 1) Outer Channel, 2) Central Sector, 3) Southern Sector, and 4) Northern Sector for the surveys (Figure 6.1 Chapter 6). A long tailed boat (9HP) at 9km/hr was used to survey following each of the two routes: a) parallel transect lines, and b) zig-zag transect lines (Figure 6.2 Chapter 6). Both routes covered the Central, Southern and Outer Channel regions of the Lagoon only. The Northern Sector of the Lagoon is weed infested, covered with a high density of fixed fishing gear and shallow making it very difficult for the boat to traverse along pre-defined transect lines. The Direct Count surveys carried out by the Chilika Development Authority since 2000 (Pattnaik et al. 2007) have not detected any dolphins in the Northern Sector of the Lagoon. I previously surveyed the navigable regions of the Northern Sector in 2004 and 2005 and sighted dolphins only in a dredged channel. Thus only this dredged section of the Northern Sector was included in the surveys (Figure 6.2 Chapter 6).

Approach and Group Data

As explained in Chapter 6, every time dolphins were sighted, the group was approached at a slow speed, to minimize disturbance. When the boat was within 100m of the dolphins, the engine was stopped and oars were used to get closer to the animals. While the primary observer photographed individuals, secondary observers counted the number of animals in the group, noted their GPS location and behavior and collected environmental data.

Defining a Group

Some researchers have defined groups of dolphins based on either 'coordinated activity' or distance measures (Mann 1999), whereas other researchers have chosen to combine proximity and behaviour to define a group (Whitehead et al. 1992; Parra 2005). In this study, I defined a group as every dolphin within 10m of any other member of the group (Smolker et al. 1992) and displaying a similar behavioral state as defined below. It was difficult to obtain data on group composition. Females were identified based on the presence of juveniles or a calf in mother-calf position (see Appendix C). The main states of behavior recorded were: (1) socializing, (2) feeding, (3) milling, (4) traveling, and (5) resting (described in detail in Chapter 8).

Individual Data

Individuals were identified using the photo-identification protocol (Chapter 6). The GPS 'track-log' function was used to store time on track during surveys. Location data at the individual level was thus obtained by matching the time stored in the photo-file to the track log from the GPS 'track' function.

7.2.3. Data Analysis

Using data from complete surveys only, I first separated the location points of groups into Outer Channel and Central-South Sector locations. To estimate the Extent of Occurrence, Area of Occupancy and Utilization Distribution I used *sighting locations of independent dolphin groups*. Independence of groups within the same survey day was maintained by using locations separated by at least one hour. To test for site-fidelity and estimate home ranges, I used independent *sighting locations for individual* Irrawaddy dolphins. All individuals sighted more then eight times and separated by a day were included in the home range analyses.

7.2.3.1. Occurrence and Occupancy

I calculated Minimum Convex Hulls based on presence-only data to estimate the range of the Chilika dolphin population. Convex Hulls provide a general measurement of the Extent of Occurrence but this estimate is a rather inaccurate measure of the actual habitat used by the animals, because it does not exclude regions which dolphins do not or cannot use (e.g., islands). In the case of Chilika Lagoon, the simple convex hulls included islands, the mainland and regions that were too shallow for dolphins to occupy. I therefore calculated the 'Area of Occupancy' with the 'α Hull' application (Burgman & Fox 2003), a generalization of Convex Hulls. Alpha Hulls help to remove discontinuities within the range of the species, by calculating a cut off value for lengths of lines connecting points that form the polygon.

I followed the procedure detailed by Burgman and Fox (2003), and made a Delauny Triangulation of the coordinate locations for the dolphin schools obtained from boat based surveys in the Lagoon. The lengths of all lines in the Delauny Triangulation were measured and the average calculated. I then calculated cut off points based on several multiples (α) of the average line length. I chose the value that retained the maximum number of locations but removed lines that crossed over islands or the mainland. This process included lines that joined distant points and but excluded areas which were unlikely or rarely used by the animals.

7.2.3.2. Utilization Distribution of the Population

The degree to which animals actually use the areas within their 'range' is called their 'Utilization Distribution'. The Utilization Distribution is the probability associated with each unit area of an individual's home range derived from records of the individual at given locations (Hooge et al. 1997). The robust Kernel method (Worton 1989) with the smoothing factor calculated using least-squares cross validation (LSCV) calculates density functions for 95% and 50% probability in the form of probability contours. By convention, when this technique is used at the individual level, the 95% probability contour is the representative range of an animal and the 50% contour is the core area of its activity. To produce a Utilization Distribution for Irrawaddy dolphins in Chilika Lagoon, I used this technique at the population level using independent groups as *'individuals'* to calculate the overall Utilization Distribution of all dolphins in the Lagoon.

I calculated the probability associated with each unit area of the population's Area of Occupancy derived from records of independent groups at given locations. There are several potential problems with using a probabilistic modeling method such as the Kernel method at the population level: (1) the method is sensitive to unequal survey effort, and (2) sites where the species has not been detected are not necessarily indicative of non use, and (3) spatial autocorrelation can occur as a result of counting the same sampling unit more than once on the same survey. I dealt with these issues by: (1) using location data based only on groups from complete surveys for each month of the study period, (2) separating the locations from the Outer Channel and the South-Central Sectors to avoid including areas where animals were not observed, (3) using data for groups that were located at least ten minutes apart from each other to minimize the likelihood of including the same group more than once in a single survey; (4) not using locations resulting from records of changed behaviors of the same group.

7.2.3.3. Corridors of Movement

I used the Local Convex Hulls (LoCoH) extension in ArcView 3.3 to identify corridors connecting the two representative and core areas used by the dolphins in Chilika by treating records of independent groups at given locations as 'individuals'. The Local Convex Hulls method is based on creating nearest-neighbour convex hulls (Getz & Wilmers 2004). The Local Convex Hulls method creates local hulls around a group of points formed from k nearest neighbors, where k is specified by the user. I used a range of k values from 5…10. For each k value, the convex hulls generated were merged one by one, from smallest to largest, until 10% of points were included, creating a 10% isopleth. The 10% isopleth outlined the most heavily used area, while the 100% isopleth included all convex hulls and shows the entire area used. The method better approximates areas at different values of k, ignores duplicate points and maintains the rule of 'minimum covering of spurious holes' in the distribution. Local Convex Hulls are very suitable for difficult landscapes such as lakes and steep terrains where there could be corridors, islands, and empty spaces (Getz & Wilmers 2004) and are thus very suitable for Chilika Lagoon. The method is designed for large data sets from satellite telemetry and radio collaring for individuals rather than groups, which is one of the limitations of the way I used the method here.

7.2.3.4. Individual Home Ranges

I calculated individual ranges (spatial area where an animal was observed during the study period—Hooker et al., 2002) for dolphins sighted nine times or more, separated at least a day apart. Probabilistic methods (i.e., Kernel Range, Local Convex Hulls) require a large number of sighting locations, and often produce disjunct ranges when using small sample sizes (Powell 2000). As my sample size was small with a maximum of 20 sighting locations for one individual, I used Minimum Convex Hulls for all individuals sighted more than eight times to estimate individual home ranges. I used the Local Convex Hulls method only for individuals sighted 15 times or more. Data were inserted into ESRI Arcview 3.1 and analysed using the Animal Movement Analyst Extension (Hooge & Eichenlaub, 1997) and the Local Convex Hulls extension (Getz & Wilmers 2004). The technique was adapted to exclude land masses whenever the Convex Hulls included them.

7.2.3.5. Site Fidelity of Individual Dolphins

I measure the standard distance deviation (S_{xy}) using the CrimeStat spatial statistics software to investigate if individual dolphins displayed fidelity towards specific areas within Chilika Lagoon. The standard distance deviation is the spatial equivalent of the standard deviation (Levine 2002). The S_{xy} measures the standard deviation of the distance of each individual dolphin location from their mean center:

$$S_{xy} = \frac{\sqrt{\sum (X_i - \overline{X})^2 + \sum (Y_i - \overline{Y})^2}}{N \quad 2}$$

where Xi and Yi are the coordinates of individual dolphin locations (projected into Universal Tranverse Mercator Zone 45N), $\overline{X}$ and $\overline{Y}$ are the means of each coordinate, and N is the total number of times an individual animal was sighted. Since there are two constants ($\overline{X}$ and $\overline{Y}$) from which S_{xy} is calculated, two is subtracted from the number of points to produce an unbiased estimate of standard distance (Levine 2002). To provide a balance between the representativeness of the data (e.g., including the maximum number of individuals) and its reliability (e.g., including individuals with maximum sighting frequencies, Chilvers and Corkeron 2002), S_{xy} was calculated only for individuals that were seen on more than eight occasions throughout the study period, separated at least a day apart. The more dispersed the individual locations were, the larger the standard distance deviation and the less faithful an individual was to a specific area within the study area.

7.3. Results

7.3.1. Extent of Occurrence and Area of Occupancy of Population

I obtained 198 locations of dolphin groups from six surveys in the 2004-2005 dry season and 371 locations from eight surveys in 2005-2006 dry season. I calculated the Extent of Occurrence from the Minimum Convex Hulls including all 569 locations to be <330km^2 (Figure 7.1). The Area of Occupancy in Chilika calculated from α Hulls built from the same dataset was <131km^2 (Figure 7.2).

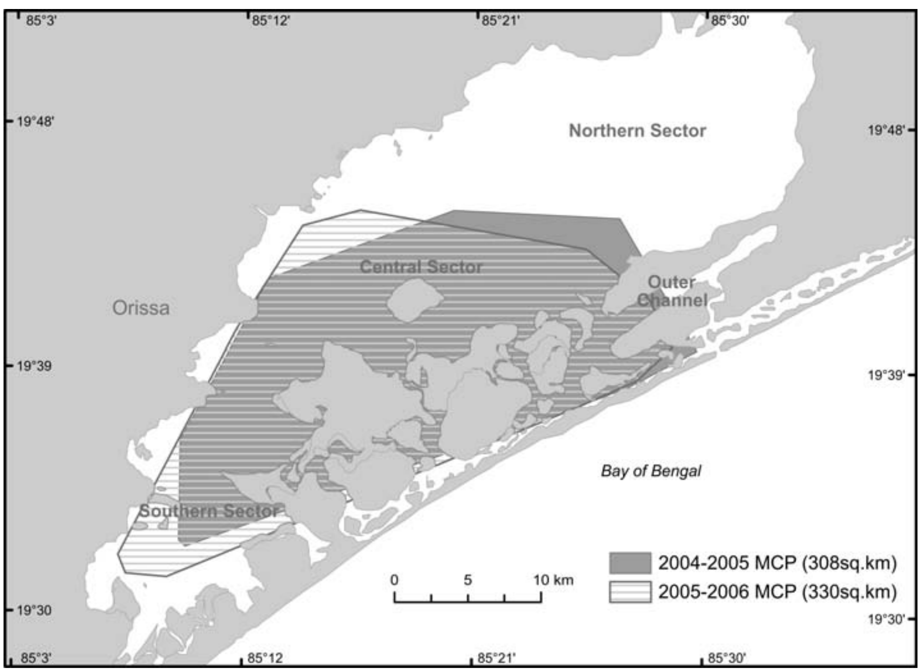


Figure 7.1. Minimum Convex Hulls showing the Extent of Occurrence of Irrawaddy dolphins in Chilika Lagoon, estimated with all sighting locations within the polygon boundary.

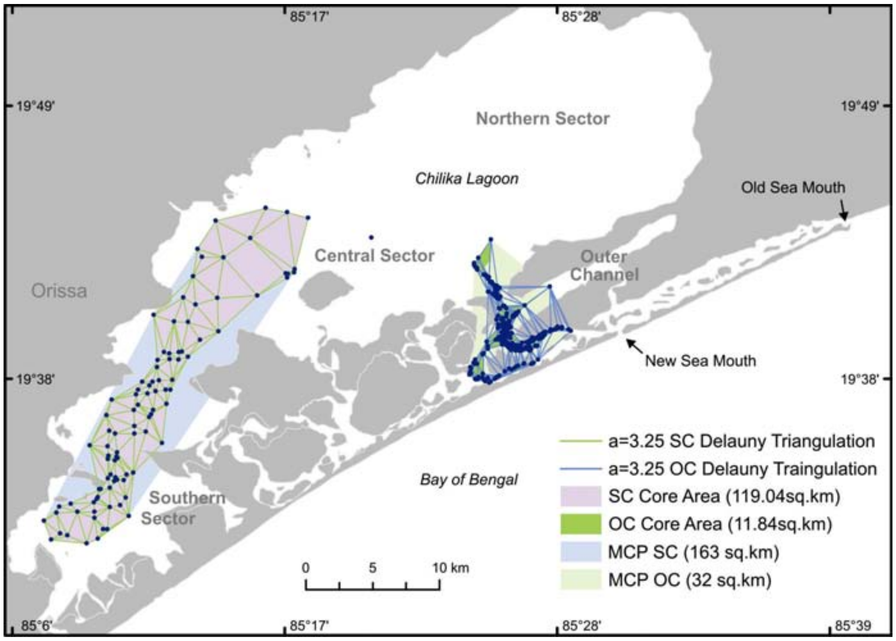


Figure 7.2. The Area of Occupancy (Pink=119km^2 in the South Central Sector and Green=11.84km^2 in the Outer Channel of Chilika) using Alpha hulls (Burgman & Fox 2003)and Delauny Triangulation to remove lines that were greater than 3.25 times the shortest line in the triangulation(alpha=3.25). The Minimum Convex Hulls are shown in the South-Central Sector (Light Blue=168km^2) and in the Outer Channel (Light Green=32km^2) to show the maximum area used.

7.3.2. Utilization Distribution of the Population

The Utilization Distribution for the population using Kernel methods estimated the core area of activity (50%) in the Outer Channel to be 12km^2 and the core area of activity in the Central-South Sector to be 49km^2 (Figure 7.3). The representative areas (95%) in the Outer Channel and in the Central-South Sector were 47km^2 and 233km^2 respectively.

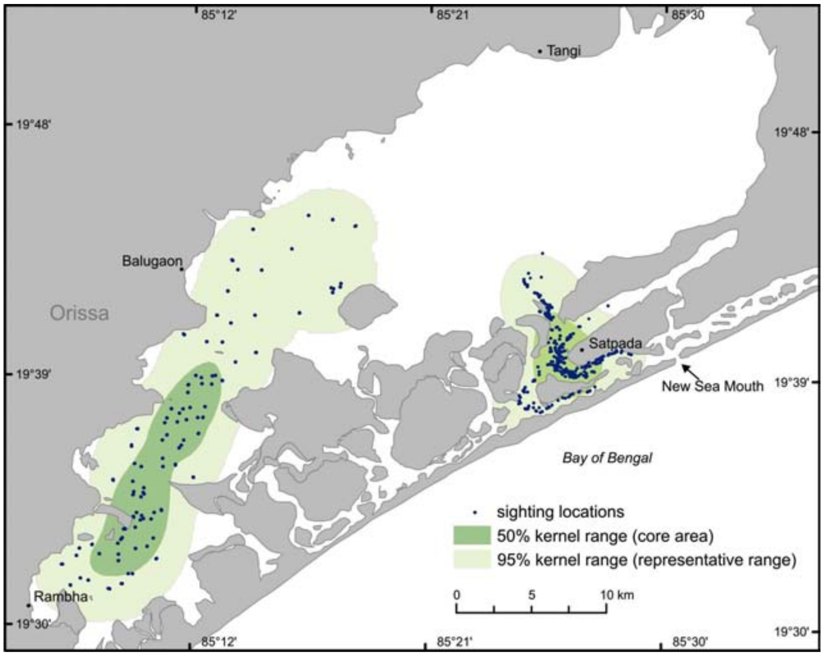
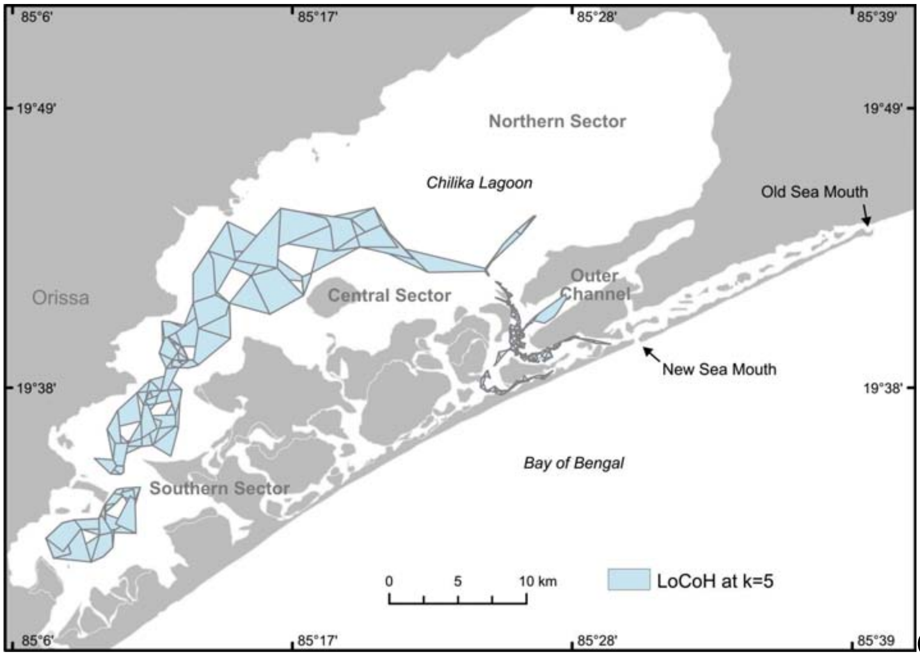


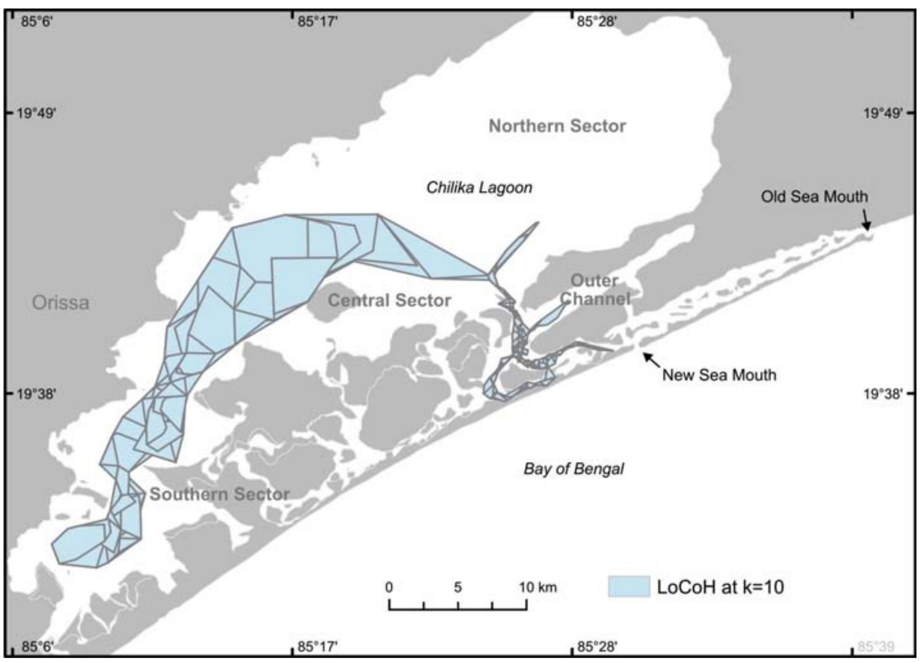
Figure 7.3. Core areas (50% kernel range-green) and representative ranges (95% kernel range-grey) of Irrawaddy dolphins in the Outer Channel and South-Central Sector of Chilika Lagoon. The data from the two regions were processed separately to estimate core and representative areas within them.

7.3.3. Corridors of Movement

The Local Convex Hulls analysis for values of k=5…10 showed a discontinuity in the number of spurious holes filled between k=5 and k=6 with gradual filling thereafter. The results indicated that the distribution shows connectivity between regions where location densities were minimal even at the conservative value of k=5 (Figures 7.4a, b) and suggested that regions between the South-Central and Outer Channel that were not included in the representative range were used by dolphins.



(A)



(B)

Figure 7.4. Local Convex Hulls based on (A) five and (B) ten nearest neighbours for independent Irrawaddy dolphin group locations. This diagram suggests regions between the core areas in the Outer Channel and South-Central Sectors of Chilika Lagoon that are traversed by animals.

7.3.4. Site Fidelity of Individual Dolphins

Individual dolphins showed varying degrees of site fidelity. Thirty-three (41%) of the 80 identified dolphins were identified more than eight times in the study period (Chapter 6 provides details about the number of dolphins sighted every month in the study area). The standard deviation distance of each individual from its mean centre varied from 0.33km to 14.33 km (Figure 8.2). Over 80% of the individuals were always found within 10km of their mean centre.

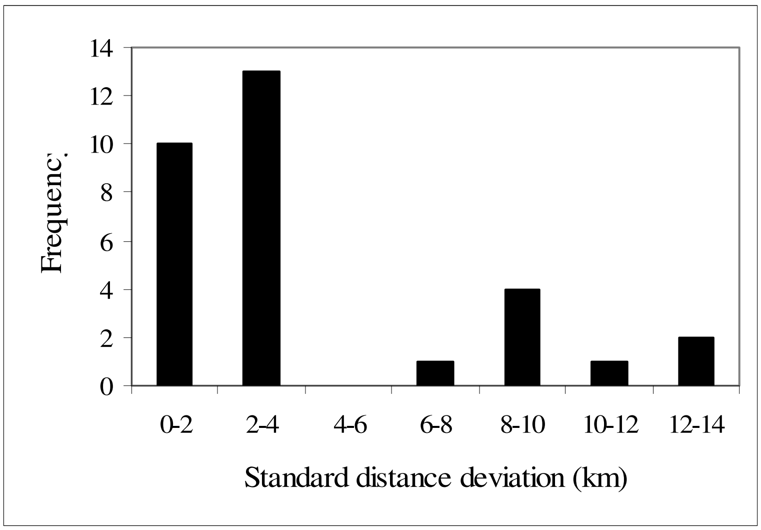


Figure 7.5. Frequency distribution of the standard distance of deviation of each individual dolphin location from its mean centre for all Irrawaddy dolphins identified more than eight times in Chilika Lagoon, India between 2004 and 2006

7.3.5. Individual Home Ranges

The Minimum Convex Hull ranges of individual Irrawaddy dolphins sighted more than eight times (Figure 7.6) suggested that most animals had similar, small ranges while only a few animals had larger ranges (Appendix E, Table 7.1). Range sizes varied from 1.7km^2 to 186 km^2 (Table 7.1, Figure 7.7) with an average of 24.81km^2. There was a large overlap among individual ranges (Figure 7.8), with 11 individuals exploring the entire study area (termed as 'explorers') whereas 19 individuals were not observed out of their core areas (termed as 'stayers'). Seven individuals had ranges that indicated mild exploration but not of the entire study area (see Appendix E). A comparison with estimated home ranges based on 70% isopleths of Local Convex Hulls for individuals sighted 15 or more times gave core areas of these individual dolphins (Table 7.2). These core areas gave much smaller estimates of home ranges than Minimum Convex Hull estimates (Table 7.2) suggesting that where the data provides greater than 15 sighting locations, Local convex hulls can provide individual core areas and home ranges, while the 100% convex hulls estimate the extent of movement of these animals away from their core areas.

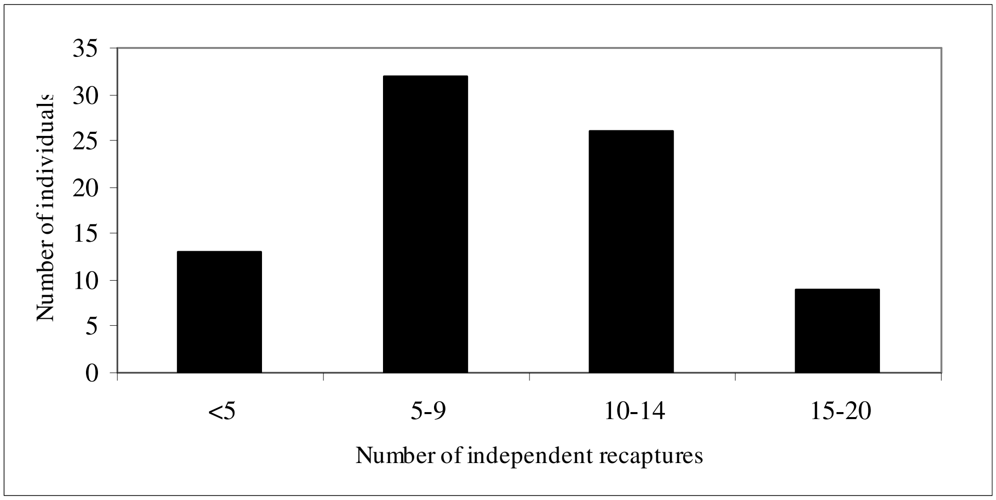


Figure 7.6. Number of resightings of identified Irrawaddy dolphins in Chilika. Only individuals sighted more than eight times were included in home range estimation.

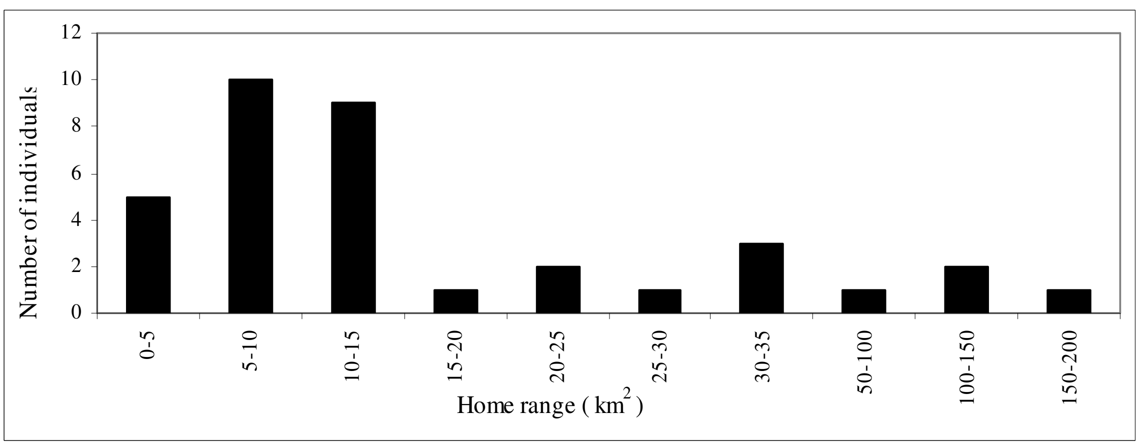


Figure 7.7. Histogram showing the distribution of home range sizes for individual dolphins with more than eight independent sighting locations.

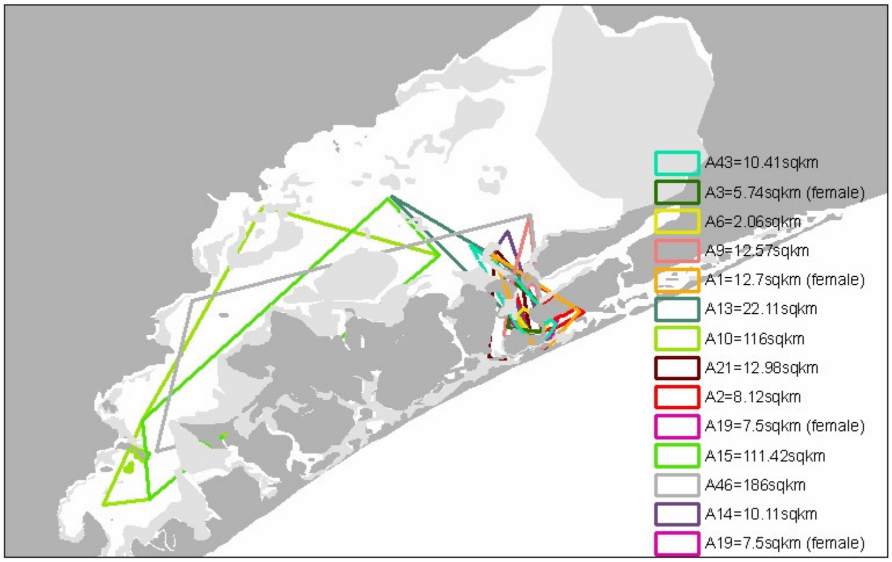


Figure 7.8. Home ranges for individual Irrawaddy dolphins with more than eight independent sighting locations in Chilika Lagoon, India between 2004 and 2006. The home ranges were calculated using Minimum Convex Hulls.

Table 7.1. Estimated home ranges for individual dolphins (females identified based on the presence of calves or juveniles) including two individuals sighted only six times.

ID	Number of recaptures	Home range from MCP (km^2)	Sex
A5	9	1.78	female
A6	10	2.06	
A37	6	2.6	
A34	12	2.63	
A38	7	3.5	
A31	13	3.69	
A3	12	5.74	female
A35	11	5.87	
A30	13	6.34	
A44	12	7.49	
A19	12	7.5	
A2	12	8.12	female
A12	13	8.15	
A28	13	8.27	
A20a	12	8.27	
A1	17	9.97	female
A20	18	10.32	
A43	15	10.41	
A48	9	11.09	

ID	Number of recaptures	Home range from MCP (km^2)	Sex
A14	13	11.85	
A7	14	12.57	
A9	10	12.57	
A22	11	12.76	
A21	11	12.98	
A11	14	14.44	
A27	14	16.52	female
A17	10	21.39	
A13	18	22.11	
A77	13	25.25	female
A41	17	26.91	
A74	11	30.11	
A25	12	34.14	
A29	19	35	female
A45	20	88.79	
A15	6	111.42	
A10	9	116	
A46	10	186	

Table 7.2. Home range estimates based on Minimum Convex Hulls and Local Convex Hulls where n (the number of recaptures per individual) was 15 or more. A 100% isopleth includes all the sighting locations like a Minimum Convex Hull, while a 70% isopleth includes 70% of the locations.

ID	n	MCP (km^2)	LoCoH (km^2) isopleth %	
			100%	70%
A45	20	88.79	87.96	6.19
A29	19	35	29.65	2.55
A20	18	10.32	10.17	6.5
A13	18	22.11	21.43	1.11
A41	17	26.91	16.77	4.02
A1	17	9.97	7.76	1.34
A43	15	10.41	8.93	3.2

7.4. Discussion

Space Use

In the dry season, Irrawaddy dolphins in Chilika Lagoon use about half of the total available area (approximately 800km^2). I observed the dolphins in less than 400km^2 of the Lagoon including a 280km^2 representative area and a 61km^2 core area in the dry season. There are few comparable data sets from other riverine and lagoonal populations of Irrawaddy dolphins. An Australian snubfin dolphin population of approximately 76 animals has a reported representative area of 93-104km^2, and a core area of 16-27 km^2 (Parra 2005) stretching over two coastal bays in Queensland.

This study suggests that Irrawaddy dolphins in Chilika Lagoon prefer certain core areas in the Lagoon during the dry months of the year. Fishing activity is at its highest during the dry season, and fixed fishing gear is widespread, potentially obstructing dolphin movement (and the survey vessel), thus reducing the actual size of the dolphins' representative and core areas.

Results from Chapter 4, suggest a change in distribution of Irrawaddy dolphins in Chilika over time, possibly related to changes in habitat quality or a reduction in population size. If size and quality of the habitat were suitable and restored via habitat management programs, and their prey was randomly distributed, the dolphin distribution would be expected to expand. The results from the Site Fidelity analysis suggest that most animals are loyal to their preferred areas, and so the temporal change in distribution reported in Chapter 4 could represent loss of groups of dolphins rather than a shift in home ranges, or a loss of 'explorers' from the population.

Movement Corridors

The discontinuity between the two representative areas used by Irrawaddy dolphins in Chilika Lagoon does not indicate two geographically isolated populations. Using photo-identification I confirmed that individual dolphins move between the Outer Channel and the South Central Sectors of Chilika Lagoon (Figure 7.7). Areas that are not part of the representative or core areas are thus used by dolphins as corridors of movement. Considering the local scale of my study and the limitations imposed by the closed nature of the Lagoon, the results indicate that even at fine scales, corridors of movement are probably very important to sustain the population in the long term. I presume that these corridors are responsible for maintaining the social (Chapter 8) and genetic flows between groups and have management implications for conserving the Irrawaddy dolphins in Chilika Lagoon.

Individual Home Ranges

In my study, very few individual Irrawaddy dolphins had large home range sizes and a large number of individuals had an overlap in home ranges with a minimum home range of 1.07km^2 and maximum of 186 km^2. The dolphins were spatially limited by the enclosed nature of the lagoon, a situation that contrasted with the large open areas available to coastal populations or linear stretches of rivers occupied by some populations of *Orcaella*. Thus the spatial configuration of habitat could influence the group sizes and social structure of the population, which I shall explore in Chapter 8. Irrawaddy dolphins in the Mekong River had average home ranges of 11km^2 in the dry season and 42km^2 in the wet season (Beasley 2008) (Chapter 3). During the wet season two animals moved between pools by traveling 52 to 78km. Australian snubfin dolphins (Parra 2005) in Cleveland Bay had an average home range of 69km^2 with just one individual having a small range of

4.7km^2. There was an overlap of 54km^2 in home ranges with a maximum home range of 108km^2.

The results from this chapter are crucial to the assessment of the population status of Irrawaddy dolphins in Chilika (Chapter 10). The species distribution does not extend into the sea and there are no other subpopulations in the vicinity of Chilika (see Chapter 5). Areas of Occupancy and movement corridors need to be considered in conjunction with the quality and carrying capacity of the habitat, to assess the status of the Irrawaddy dolphin population in Chilika.

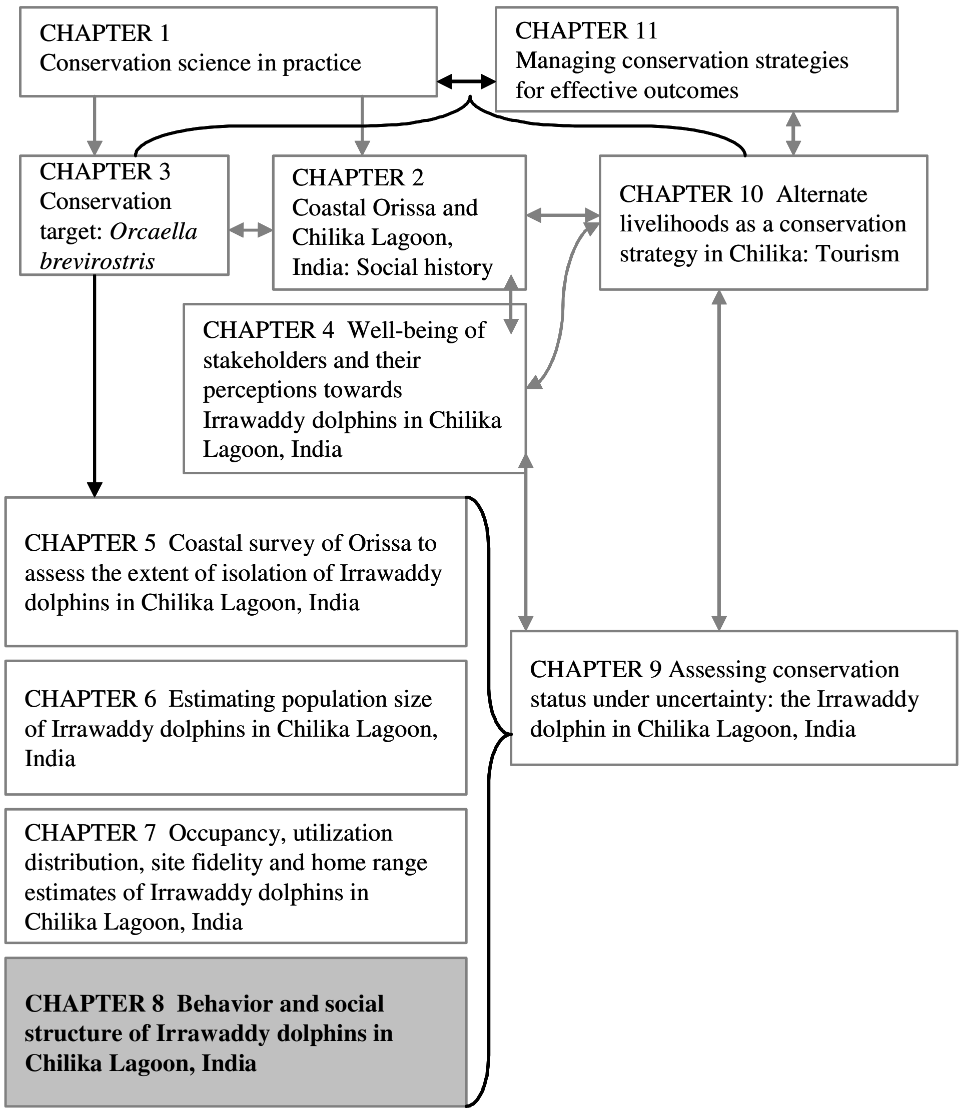
7.5. Chapter Summary

- Estimates of Extent of Occurrence and Area of Occupancy in relation to space use are required to model changes in habitat availability and quality and to assess the conservation status of wild populations at local and regional scales.
- I used Minimum Convex Hulls, Alpha Hulls and Local Convex Hulls to provide estimates of the area used by Irrawaddy dolphins in Chilika Lagoon and to map movement corridors.
- I estimated the total Extent of Occurrence for Irrawaddy dolphins in Chilika as <330km^2; and the Area of Occupancy to be <131km^2, both of which are less than half of the available habitat. The quality and carrying capacity of this habitat play an important role in the long term survival and health of dolphins in Chilika.
- Using ArcGIS based kernel methods to estimate the Utilization Distribution at 95% and 50% probabilities, I found that Irrawaddy dolphins do not use the Lagoon uniformly and that there are two core areas, one in the Outer Channel and one in the South-Central Sector
- The Site fidelity of individual dolphins is high with more than 80% of the individuals remaining within 10km of their mean centre.
- Home range estimates vary from 1.7km^2 to 186km^2 for individuals sighted more than eight times between 2004 and 2006. There was a large overlap in home ranges which could be a product of habitat availability, resource availability or mating

systems. Results from the Local Convex Hull application suggest that core areas of dolphins are much smaller than estimates of Minimum Convex Hulls

- Further research is required to assess the role of ecological factors on the social organization of the Irrawaddy dolphin population. I explore some of these factors in Chapter 8.

8 BEHAVIOR AND SOCIAL STRUCTURE OF IRRAWADDY DOLPHINS IN CHILIKA LAGOON, INDIA



In this chapter, I use group and individual level data to understand the behavioral ecology of Irrawaddy dolphins in Chilika Lagoon, India. I explore space use by testing the association between dolphin group size and behaviour in core areas identified in Chapter 7, and with ecological variables of salinity and water depth. I assess the association patterns between identified individuals sighted more than four times in groups in which more than 50% of the individuals were identified. I compare my results with other studies on

Irrawaddy dolphins and suggest that social structure is a function of the interactions among population size and the spatial distribution and quality of feeding habitats.

8.1 Introduction

Social behavior evolves as an adaptation to maximize fitness, given a particular set of ecological pressures (Wrangham 1987). Complex interactions between predation pressure, resource availability and intra-specific interactions all influence grouping and social structure within phylogenetic constraints (Crook 1970; Clutton-Brock 1974; Geist 1974; Jarman 1974; Lott 1984; Maher & Lott 1995, 2000). Life history and phylogeny interact with the distribution of resources, mates and predators to determine the mating strategy of a species at a particular location (Rudman 1998). The evolutionary product of these influences is the different mating systems – monogamy, polygamy, polyandry and polygandry, which define the social structure of a community. When studying marine mammals, it is often not possible to identify the sex and age class of individuals, a constraint that makes it impossible to answer fundamental questions of behavioral ecology – such as the relationships within and between sexes, and how mating systems influence social organization. Rather marine ethologists tend to take a bottom-up approach to identifying the constituents of a social system and then use the results to frame hypotheses about the role of social and ecological constraints influencing social structures.

Space use and ranging patterns are important influences shaping social and mating systems in mammals and birds (Emlen & Oring 1977; Clutton-Brock 1989). The amount of overlap in home ranges is hypothesized to provide indirect information about social interactions (Shier & Randall 2004). I analyzed the group sizes of Irrawaddy dolphins in Chilika Lagoon to identify the most basic unit of social organization. I analyzed group-size data associated with different kinds of behavioral states, environmental variables and localities to test if the grouping behavior of Irrawaddy dolphins is more influenced by differences between localities, (which may or may not have a good supply of prey) or if the kinds of behaviors exhibited are better related to group size.

Classical social ecologists studied grouping patterns before analyzing social relationships because grouping patterns require less information (Crook & Gartlan 1966; Clutton-Brock 1974; Chapman et al. 1995). This approach is still often used when species are first studied. The precise ways in which ecological pressures influence grouping behavior is unclear but various theories exist across a range of fauna, as discussed below. For example, large species in regions of low food supply usually live in small groups (Leighten 1986), whereas co-operative hunting and joint defense of resources usually entails living in larger social groups (Packer 1986).

Society emerges from the pattern of social interactions among individuals over time (Hinde 1976). The social bonds that form society usually have a persistent affiliative component. These bonds differ in different societies of mammals. Non-human primates are the most extensively studied mammals other than people from the perspective of sociobiology. Wrangham (1987) suggested that different primate species (Chimpanzees, *Pan troglodytes*; Bonobos, *Pan paniscus* and Gorillas, *Gorilla gorilla*) living under similar ecological constraints and facing similar risks from predators, had different grouping behaviors and social organizations (Wrangham 1987). This finding confirmed the complexities and varieties of social relationships that exist among closely-related mammalian species. Wrangham found that bonobos live in large groups of about 100 animals and exhibit a highly fluid and cooperative social system. In contrast, chimpanzees form tight social groups of not more than 25 individuals, with strong female-female bonds and gorillas are not found in groups larger than 17 to 20 individuals (Wrangham 1980), illustrating the inter-specific variations in social structure within a taxonomic group.

In many non-human mammalian species, intraspecific variability in social structure is also common suggesting that ecological variables like habitat type, food availability and predator characteristics result in different populations of the same species having different social structures(Crook 1970) (Clutton-Brock 1974; Geist 1974) (Lott 1984; Byers & Kitchen 1988; Maher & Lott 1995). Four of the five species of monogeneric equids (Plains zebra, *Equus quagga;* Mountains zebra, *Equus zebra;* Gervey's zebra, *Equus grevyi* and the African wild ass *Equus africanus*) show one of two types of social organization (Rudman 1998): 1) solitary individuals who defend territories only when an oestrous female is present; and 2) a harem band where a group consists mainly of an adult male with one or more adult females and their young (Ginsberg & Rubenstein 1990; Klingel

1998). Spotted hyaenas in the Serengetti form loose solitary groups, whereas those in the Ngorongoro crater form large cohesive social groups (clans); a difference attributed to the scanty food supply in the Serengetti, in contrast to the many large bodied prey in Ngorongoro that require co-operative feeding strategies to catch and kill (Kruuk 1972). Numerous other vertebrate examples demonstrate the complexities in social structures resulting from resource distribution and predator pressure.

In cetaceans, social structure can be described by quantifying the level of associations between identifiable individuals found in a 'group' (in spatial proximity and showing similar behavior) and assessing if the association changes over time (Whitehead & Dufault 2001). Detailed studies of association patterns in cetaceans have been limited to relatively few species including bottlenose dolphins, *Tursiops sp.* (Smolker et al. 1992; Brager & Schneider 1998; Quintana-Rizzo & Wells 2001; Chilvers & Corkeron 2002; Owen et al. 2002; Wells 2003; Lusseau et al. 2003), long-finned pilot whales, *Globicephala melas* (Ottensmeyer & Whitehead 2003), Hector's dolphins, *Cephalorynchus hectori* (Slooten et al. 1993; Braeger et al. 1999), Atlantic spotted dolphins, *Stenella frontalis* (Herzing & Brunnick 1997), and killer whales, *Ornicus orca* (Baird & Whitehead 2000).These studies demonstrate the variability of social structure among cetacean species ranging from stable matrilineal groupings (e.g., killer whales) to fluid fission-fission grouping patterns (e.g., bottlenose dolphins). This variability could be phylogenetic, related to the distribution of prey resources or the product of predator avoidance strategies. In the fission-fusion society exhibited by some bottlenose dolphin populations, animals avoid competing over food resources by dispersing over the available habitat. However, other factors like predator avoidance, reproductive state and mating strategy also influence the relationship between individuals and social structure (Connor et al. 1992; Connor & Heithaus 1996; Connor 2000).

Both inter-specific variability and within-species plasticity have been found in the social structure of cetaceans. At the population level, social structure is the system within which defense, foraging, disease spread, information transfer, mating and reproduction take place (Axelrod & Hamilton 1981). Intraspecific differences in social structure of cetaceans have been attributed to habitat type as in the case of bottlenose dolphins living in socially-stable populations in a sheltered habitat like Sarasota Bay (Wells 2003); or isolated regions like Doubtful Sound, New Zealand (Lusseau et al. 2003). In contrast, bottlenose dolphins living in more open areas like Shark Bay, Australia show a fission-fusion kind of social structure in which groups are dispersed and individuals move amongst groups frequently (Connor 2000). Spinner dolphins also exhibit fission-fusion behaviors in open-water habitats (Würsig et al. 1994), but stable social structures with long term associates in isolated atolls (Karczmarski et al. 2005). Sympatric resident killer whales live in stable pods, while mammal-eating (transient) killer whales disperse from their natal pods while still retaining strong, long terms associations with a few individuals (Baird & Whitehead 2000). Given the cryptic nature of social relations and the large number of confounding factors like prey availability, predator avoidance, age-class, sex, site fidelity and phylogeny, studies of intraspecific plasticity in social structure of cetaceans are still largely descriptive, and the cause of differences between populations remain largely speculative. More robust conclusions will require replicated comparisons of independent populations of the same species in various habitat types.

The existence of *Orcaella* populations, in coastal and isolated lagoonal and riverine habitats provides an excellent opportunity to study the variation of social organization within a species that uses markedly different habitat types. Irrawaddy dolphin social structure has so far been analyzed for two riverine populations in Asia (Kreb 2000; Beasley 2008). Individual dolphins in the Mahakam River of East Kalimantan, a closed population of 48-55 Irrawaddy dolphins, show clear preference for association with certain individuals and have long-term preferred companions (Kreb 2000). Beasley (2008) found similar results for a closed population of approximately 128 animals in the Mekong River. The society is highly structured with individuals having long-term preferred associates. In the closely-related Australian snubfin dolphin *O. heinsohni*, Parra (2005) also found that the population follows a model of constant companions and casual acquaintances with strong social bonds and preferred long-term associates. Thus all three populations of *Orcaella* studied to date demonstrate similar social structures, despite differences in their habitat types.

In this chapter, I explore the social structure and group behavior of the Irrawaddy dolphin population in Chilika Lagoon. I analyzed the overall group sizes and investigated 1) if salinity and water depth influenced group size dynamics; and 2) if there was a relationship between group size and behavioral states that allow possible social influences on space use to be identified. I investigated group behaviour in the core areas of usage (identified in Chapter 7), to test if general daytime activity in the population was related to space preferences. I then used photo-identification data (Chapter 6) to conduct a preliminary investigation of the association patterns among individual dolphins. I hypothesized that habitat size would influence school dynamics and social structure, and compared my results with other studies of group size dynamics and social structure of the genus *Orcaella*. Variation in the social relationships within populations can potentially be a useful index of disturbed environments; for example, the effect of disturbed environment on abundance of bottlenose dolphins (Bejder et al. 2006b) and on grouping behavior and fitness in mammals (Johns & Skorupa 1987). Given the nature of recent and likely future changes in Chilika lagoon (Chapter 2), I discuss the conservation implications of habitat size and quality on the grouping behavior and social structure of Irrawaddy dolphins.

8.2. Methods

8.2.1. Study Area

As discussed in Chapter 2, Chilika Lagoon is a brackish water lagoon/lake located in Orissa, India (19° 28'N - 19° 54'N and 85° 05'E – 85° 38'E; Figure 2.1). The Lagoon is separated from the Bay of Bengal by a spit which is ~1.5km wide and 60km long. The Lagoon is mostly enclosed except for a single artificially dredged mouth to the sea via the Outer Channel (Figure 2.1). Details of the study area are provided in Chapter 2 and Chapter 6.

8.2.2. Survey Design

I collected information while carrying out photo-identification surveys and therefore followed the survey design outlined in Chapters 6 and 7 to collect group and individual level information.

8.2.3. Data Collection

As group data were collected as part of photo-identification surveys, I followed the protocol used in Chapter 7 to approach groups and obtain group-level information regarding size, composition whenever possible and predominant group behavior.

Behavioral data

Behavioral samples are collected as events and states (Altmann 1974). A behavioral state is a long-duration behavior while an event is a short-duration behavior. When a group of dolphins was first sighted, I scanned the group and assessed its predominant surface behavioral state. After this initial assessment, group behavior was recorded every time the behavioral state changed. The vessel remained with a group until the dolphins had moved away and did not resurface for at least 10 minutes.

Dolphin schools were classified into one of six main behavioral states (Connor 2000):

- Resting (R): Animals remaining on the surface with short and slow dives and in the same location, with very slow movements. Sometimes slow traveling was also part of a resting phase, and was included as resting.
    - Slow traveling (ST): Dolphins moved in one direction together at a slow speed and surfaced synchronously. Slow traveling occurred in conjunction with resting behavior.
- Traveling (T): Dolphins moved intentionally in one direction with a regular pattern of surfacing and diving. Dolphins did not stay underwater for long periods and were often very fast in their movements, which I also sub-grouped as Fast traveling (FT).
- Socializing (S): Intensely socializing dolphins tended to remain in a given location. When disturbed by a boat, they typically moved only within 50m of the original

location at which they were sighted to continue socializing. Movements were very fast in intense socializing involving events like petting, rubbing, mounting and diving on top of and underneath other dolphins, chasing, flipper and fluke slaps and aerial displays. Sometimes socializing was seen in a less intense form associated with traveling or resting, where animals moving together or feeding together touched, or one of the animals leaped out of the water or spy hopped. This behaviour was often seen when a calf or juvenile was present in the group. Appendix B shows pictures of socializing behaviors.

- Milling (M): The activity was not associated with any clear direction of movement. Activity levels were low and there were no aerial displays. There was little interaction between individuals and tail-out dives occurred in one location only. Diving and surfacing showed synchronicity with slow movements and shallow dive angles.
- Foraging (F): Movements were energetic, frequent and repetitive with an extensive use of flukes and flippers to scare fish. Appendix B shows pictures of foraging behaviors and feeding. Foraging dolphins displayed some or all of the following behavioral events:

  1. Pursuing fish or carrying a fish in the mouth;
  2. Raising mud in plumes and encircling the plume either individually or in cooperation with another dolphin;
  3. Searching for fish at fixed man-made fish enclosures by moving to and fro along the net and feeding sideways from the fixed net;
  4. Herding fish in different ways, either alone or in a group seen with fish jumping out of water-

     a) 'Kerplunking' using the head, flippers and tail fluke to hit the water in conjunction with 'spitting' often seen with large schools of fish jumping out of the water;

     b) Spitting sideways associated with a fluke slap;

     c) Spitting without any fluke or flipper activity;

     d) Moving to and fro along the banks chasing fish towards land and then rushing towards the school as it moved back into the water

8.2.4. Grouping Behavior and Space Use

As explained above, every time a group of dolphins was located, I noted its initial behavioral state and group size, along with environmental data, and tried to photograph all individuals in the group (See Chapter 6 for details). I used correlation coefficients (alpha=0.05) to test if salinity and water depth influenced group size dynamics. I was not able to collect data for temperature, pH and water clarity on all the surveys because of logistical problems and acknowledge the inadequacy of the data for developing habitat preference models (which I did not attempt). Given the constrained biophysical environment of the Lagoon and the small size of the core areas used by the dolphins (Figure 7.3), my results could also reflect spatial autocorrelation rather than actual preference and should be treated with caution.

I investigated if there is a relationship between group size and behavioral states to identify possible social influences on space use. The non-parametric Kruskal-Wallis test was used to test for differences between group sizes in relation to the five different behavioral states. I tested 1) if there was a difference in how dolphin groups used the two 50% core usage areas and 2) if there was a difference in how dolphin groups used the core and the non-core areas, identified in Chapter 7 using Pearson's χ^2 test and Fisher's Exact test, by comparing the distributions of initial behavioral states in these areas.

8.2.5. Association Analysis

The analyses of association patterns were carried out in MATLAB 6.5 using SOCPROG 2.1, a series of MATLAB programs for analyzing social structure (Whitehead 2008). All dolphins identified within the same 'group' on a single day (the standard sampling period) were considered associated. If an animal was resighted on the same day, the second group in which it was sighted and all the individuals from this group were excluded from the analysis. Not all dolphins in all groups were identifiable (Chapter 6), a situation that could cause a downward bias in association indices (Chilvers & Corkeron 2002; Parra 2005; Gowans et al. 2008). I used groups in which 50% or more individuals were identified in the analysis to reduce this bias. To provide a balance between the representativeness of the data (e.g., including the maximum number of individuals) and their reliability (e.g., including individuals with maximum sighting frequencies, (Chilvers & Corkeron 2002)), only those individuals that were seen on more than four occasions throughout the study period, separated at least one day apart were included in the analysis.

I first tested the social differentiation in the population using the Social Differentiation test in SOCPROG. To estimate the strength of the relationship between dyads I calculated the Half-Weight Association Index (HWI) (Cairns & Schwager 1987):

$$HWI = \frac{x}{x + 1/2(Y_a + Y_b))}$$

where x is the number of sightings that included both dolphins A and B, Y_a is the number of sightings that included only dolphin A, and Y_b is the number of sightings that included only dolphin B. The possible values of the Half-Weight Association Index range from 0 (animals never sighted together) to 1 (animals always sighted together). The Half-Weight Association Index estimated the proportion of time each dyad spent associating. The resulting association matrices were displayed in three ways. The first was an average linkage cluster analysis, where individuals were arranged on the y axis with the strength of associations presented on the x axis. This method can give misleading results because it assumes a hierarchical distribution of association indices. Sociograms and Principal Component Analyses are better at displaying clusters based on association indices among individuals, as these approaches do not assume a hierarchically-organized social structure. I also conducted a Principal Component Analysis, in which each individual was plotted such that the distance between individuals was proportional to one minus the square root of their association. Strongly associated individuals were thus plotted together and weakly associated were plotted far apart. Negative eigenvalues are indicative of poor performance of a Principal Component Analysis (Whitehead 2008), and those greater than one indicate coordinates which explain more information than average. Lastly, a sociogram was used to represent the strength of relationships by arranging individuals around a circle and linking them via lines the thickness of which implied the strength of the relationship (Whitehead 2008).

Lagged association rates are used to test the null hypothesis of no preferred association over time (Whitehead 2008; Whitehead & Dufault 2001). I did not assess temporal patterns of association using lagged association rates as my data were limited to a time lag of one year which rendered the technique inappropriate.

8.3. Results

8.3.1. Grouping Behavior and Space Use

I estimated the size of all the groups of dolphins included in the Utilization Distribution analysis (n=569). Group sizes varied from 1-19 animals (Figure 8.1) with 25% of observations consisting of a single dolphin, 22% consisting of two dolphins and 19% consisting of three dolphins. The mean sizes of groups encountered in the Outer Channel and South Central Sectors were 3.5 animals (range=1-18 animals, mode=2) and four animals (range=1-19 animals, mode=1), respectively.

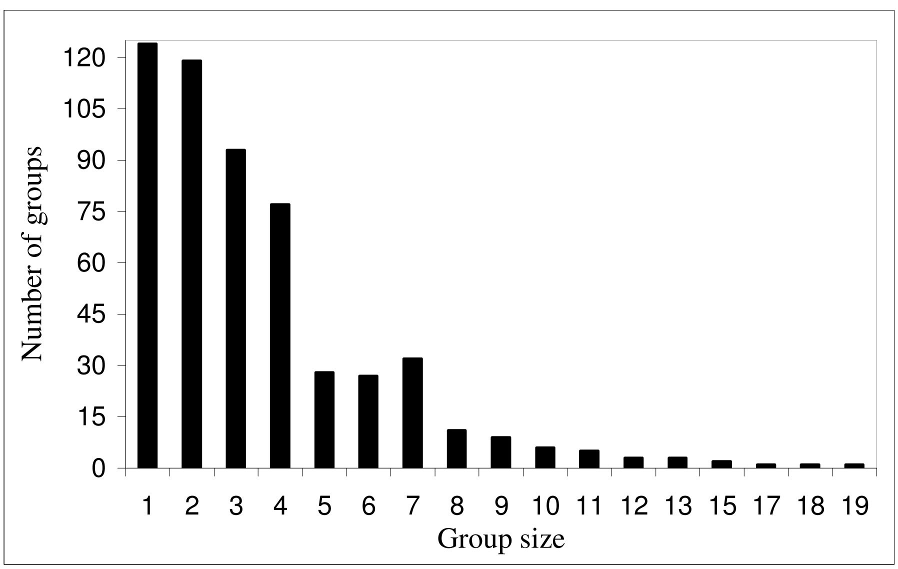


Figure 8.1. Frequency distribution of estimated sizes of groups of Irrawaddy dolphins in Chilika Lagoon, India

Group behavioral states and group size were not independent for the entire data set (non-parametric Kruskal-Wallis test, H=49.71, df = 4, P<0.001). Subsequent analysis showed that group sizes were independent of behavioral states while feeding, milling and traveling (H=1.9, df = 2, P=0.39), but were not independent while socializing (H=49.71, df=4, P<0.001) and resting (H=12.44, df=3, P<0.006). Socializing groups had an average group size of five animals per group (min=2 and max=17) but resting groups had an average group size of four animals (min= 1and max=11). During boat surveys, I observed cooperative feeding in Irrawaddy dolphins with larger groups herding large fish such as Scoliodon and Mullet (group size=7-11 dolphins), and small groups of dolphins herding small fish (group size=2-5 dolphins) along lead lines of fixed traps or along shallow regions along the shores.

Feeding (79%), milling (39%) and socializing (42%) were the three most frequent daytime (06:00am-17:00pm) behaviors exhibited by independent dolphin groups (n=569, see Chapter 7). In the Outer Channel, 48% of the groups showed feeding behaviors, 13% showed milling, and socializing was observed in 20% of the sightings (Figure 8.2). In the South Central region, 31% of the groups were observed feeding, 25% milling, and socializing was again seen in 22% of the observations (Figure 8.2).

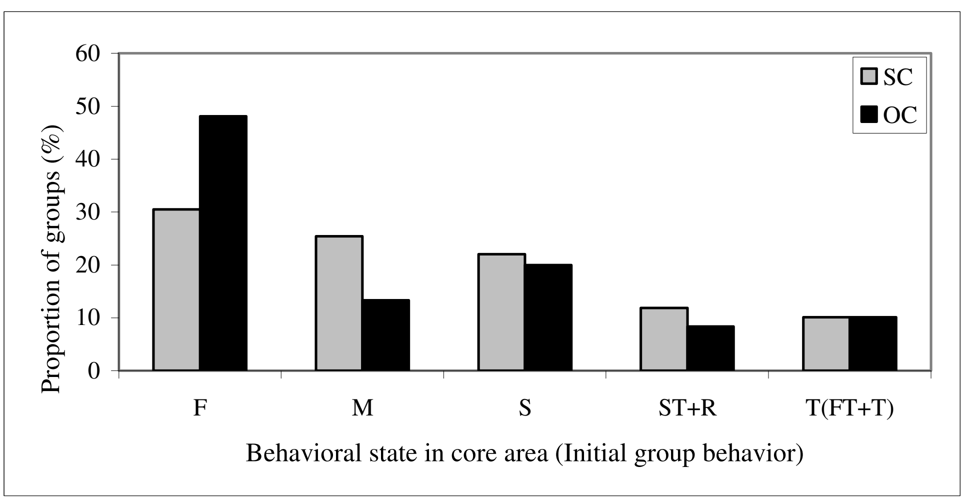


Figure 8.2. The frequency of initial behavioral states observed in the core areas of Irrawaddy dolphins in the Outer Channel (OC) and South-Central Sector (SC) of Chilika

Lagoon (M=milling, F=foraging, S=socializing, T= traveling, FT=fast traveling, ST=slow traveling, R=resting)

The difference in the overall distribution of behaviors between the core areas of Outer Channel and South Central Sectors was marginally significant (Pearson's $\chi^2 = 9.08$, df = 4, p=0.05). (Using Fisher's Exact test, the two core areas showed significant differences only in the proportion of groups exhibiting milling (df=1, p=0.02) and feeding behaviors (df =1, p=0.01), with groups in the Outer Channel core area spending more time feeding and groups in the South and Central Sectors spending more time milling (Figure 8.2).)

There was a significant difference in the distribution of behaviors in core and non-core areas (Pearson's $\chi^2 = 16.59$, df = 4, p=0.002) (Figure 8.3). Using Fisher's Exact test I found that there was a significant difference in the proportion of time animals spent feeding (df =1, p=0.008), milling (df =1, p=0.01) and traveling (df=1, p=0.03). The significance of the spatial differences in resting was marginal (df =1, p=0.05); there was no difference in the proportion of time spent socializing (df =1, p=0.63).

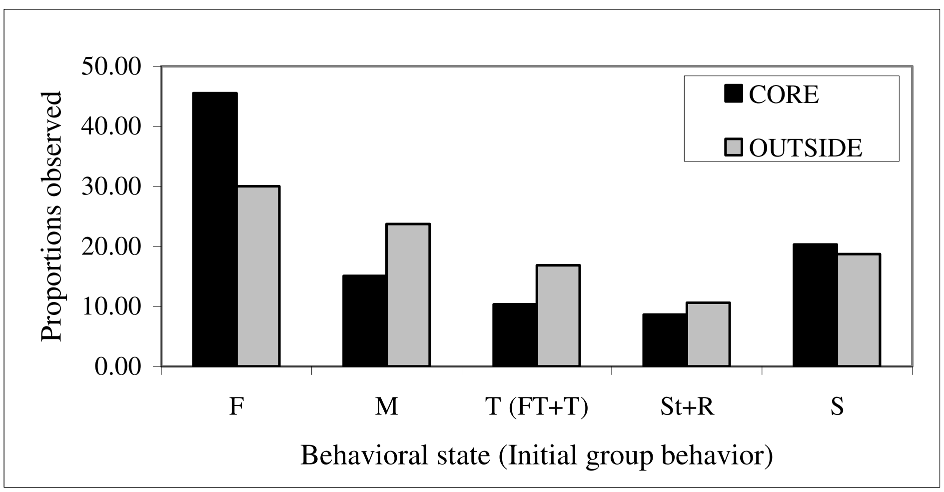
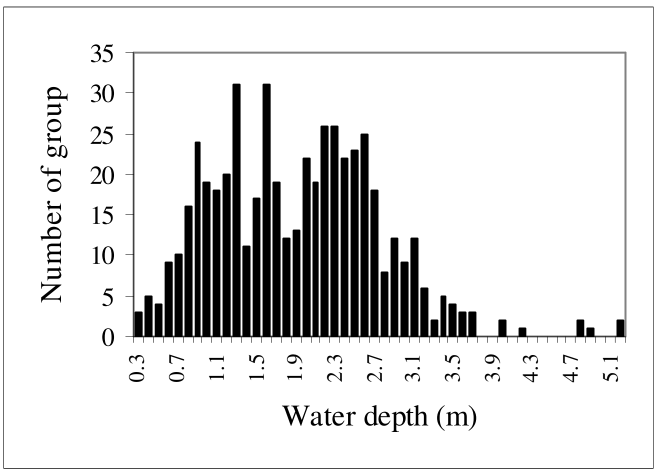
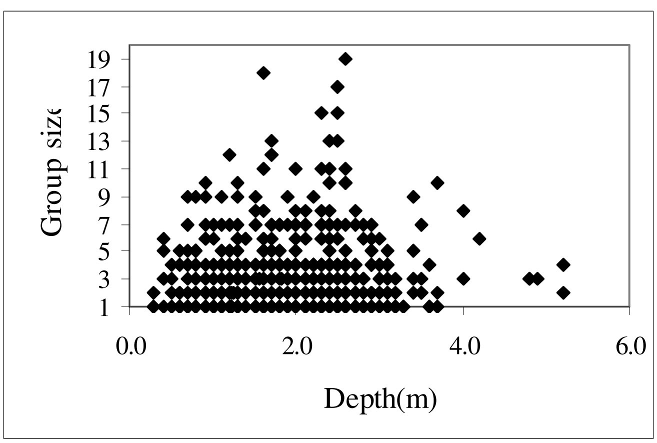


Figure 8.3. The proportions of various behavioral states observed in the core (50% kernel density) and non core areas (part of representative range outside of core area) of Irrawaddy dolphins in Chilika Lagoon (M=milling, F=foraging, S=socializing, FT=fast traveling, ST=slow traveling, R=resting)

The average water depth where dolphin groups were encountered in the Outer Channel was 1.8m (range=0.3-5.2m), and the average salinity was 19.8ppt (range-1.0ppt-45ppt). In the South Central Sector, the average water depth was 2.3m (range=1.1-3.4) and the average salinity was12.6ppt (range=4ppt-22ppt) respectively. I found that 75% of all dolphin groups were observed in water depths of 0.6-2.5m deep; and 45% of observations were in a salinity range of 6-15ppt. To test if group size was influenced by water depth or salinity, I calculated simple correlation coefficients. There was a low positive linear association between mean group size and water depth (n=517, r = +0.04, p<0.001) (Figure 8.4 a, b). For salinity, the same association was weakly negative (n=521, r = -0.06, p<0.001) (Figure 8.5a, b).

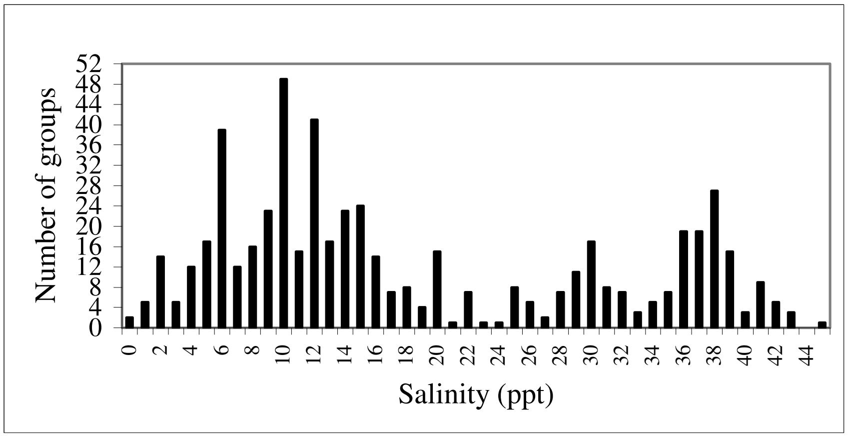


(A)

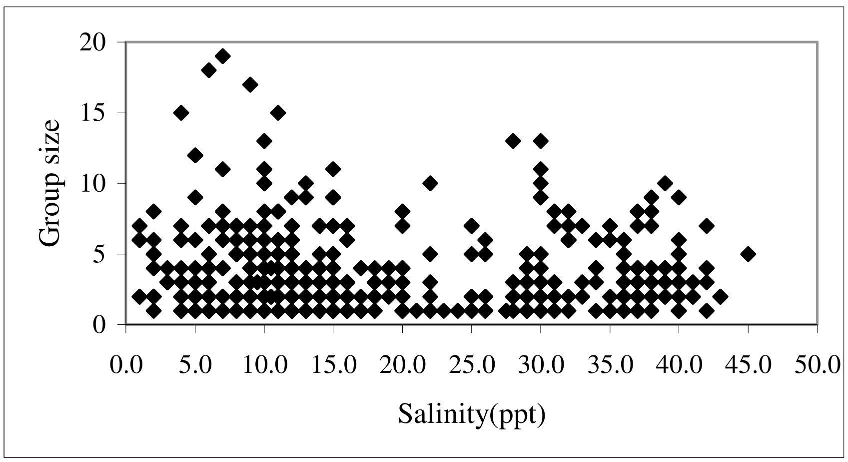


(B)

Figure 8.4. The number of Irrawaddy dolphin groups (A) and group size (B) at different water depths as observed in Chilika Lagoon, India. 75% of Irrawaddy dolphin groups were found in waters 1-3m deep. Group size was weakly positively correlated with water depth (r=0.04).



(A)



(B)

Figure 8.5. The number of Irrawaddy dolphins groups (A) and group size (B) at different salinities as observed in Chilika Lagoon, India. 45% of the groups were found in 6-15ppt. Group size was weakly negatively correlated with salinity (r=-0.06).

8.3.2 Association Patterns

I analyzed 127 groups of dolphins over 70 sampling periods (sampling period=day). Forty-eight identified dolphins that were re-sighted ≥ four times were included in the association analysis. All individuals in the analysis were adults or sub-adults as I could not identify individual juveniles and calves (Appendix C shows the different age classes).

Based on the output from SOCPROG, the estimate of social differentiation was 0.53 using Poisson approximation, indicating that the population was not a well-differentiated society

(<0.3 is regarded as a homogenous society and >2.0 an extremely differentiated society). The power of the social differentiation analyses was low 0.15 (possible range is 0 to 1).

Association Index

The distribution of maximum Half Weight Index association levels observed for each individual suggested that most individuals were not associated with any particular companion any more than would be expected if they associated at random (HWI: Figure 8.6). The average association rate per dyad was low at 0.09.

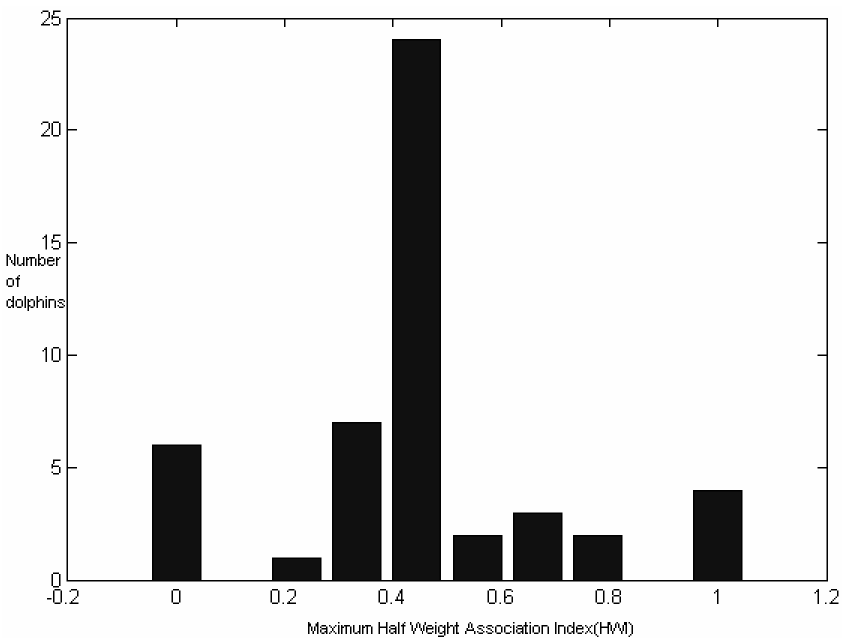


Figure 8.6. Distribution of maximum Half Weight Association index of Irrawaddy dolphins in Chilika Lagoon sighted on ≥4 days and in groups with ≥50% of individuals identified. The distribution of maximum association indices suggested that very few animals formed strong associations with a particular companion.

Average-linkage Cluster Analysis

The dendogram produced from an average-linkage cluster analysis is a hierarchical arrangement of individuals according to their association indices. The dendogram (Figure 8.7) shows that very few individuals form strong associations with other individuals. The cophenetic correlation coefficient resulting from the cluster analysis was 0.82 indicating that the dendogram is a good match to the matrix of association indices (1.0 is a perfect match and 0.0 no match). In Figure 8.7, there are five primary clusters of associating individuals with association index ≥0.5: These clusters are the only dependable associations identified.

Sociogram

The Sociogram (Association Index≥0.5 in Figure 8.8a and Association Index≥0.3 in Figure 8.8b), compares the strength of association between individual dolphins in Chilika Lagoon. Only 14 of the 48 individuals studied showed strong associations with one or more other individual.

Principal Component Analysis

Only four of the 48 eigenvalues were greater than one, indicating coordinates that explained more information that average (Whitehead 2005). No large negative eigenvalues were observed suggesting a good performance of the Principal Component Analysis. Each point on the cluster analysis represents an individual, so that the distance between them is proportional to one minus the square-root of their association: therefore, strongly associated individuals are plotted together and weakly associated ones are plotted apart (Whitehead 2005).

The Principal Component Analysis (PCA) suggested that the population of Irrawaddy dolphins in Chilika showed different types of associations: 1) some individuals did not associate strongly with any other individuals; 2) some formed a cluster, but loosely associated with other individuals; and 3) others associated strongly with at least one other individual (Figure 8.9). The analysis provides spatial context to the associations. In Figure 8.9, clusters found in the South Central Sectors are in the lower right corner, far from the clusters in the top right which are clusters found in the Outer Channel of Chilika, suggesting some spatial confounding of group identity and location.

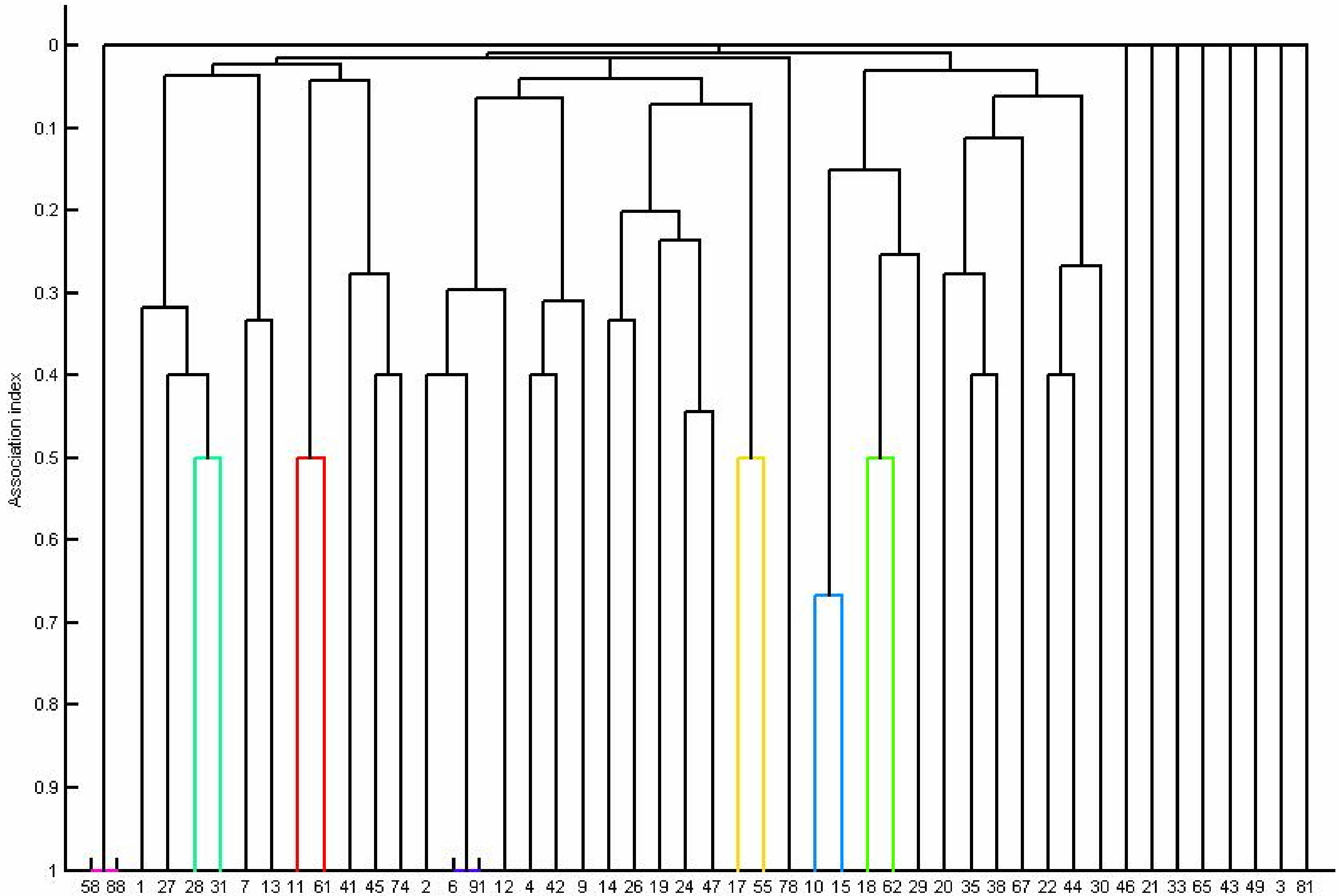


Figure 8.7. Average cluster analysis for associations between Irrawaddy dolphins in Chilika Lagoon, using only individuals sighted on ≥ 4 days and in groups with ≥50% of individuals identified. The dendogram suggested that eight animals were not associated with any other identified dolphins.

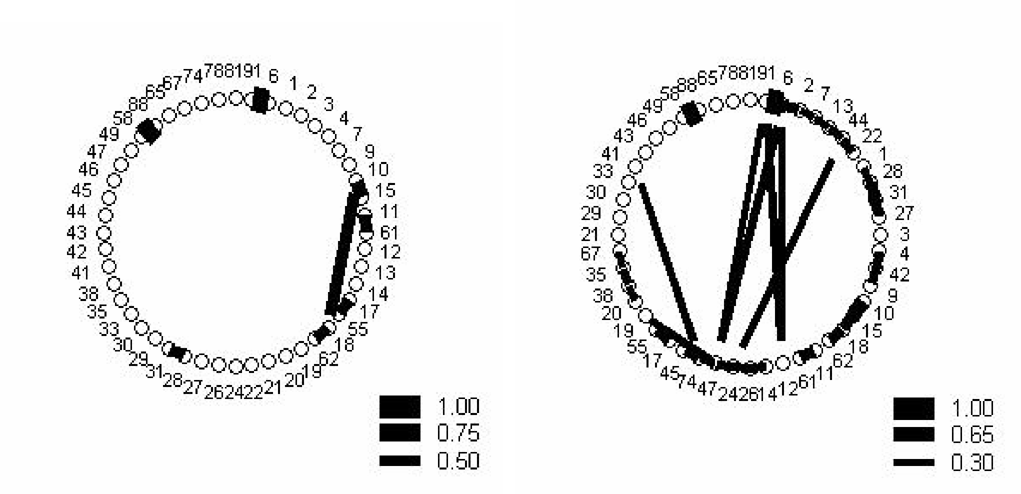


Figure 8.8. Sociograms showing that strong associations were detected between very few individual Irrawaddy dolphins from Chilika Lagoon (Association Index≥0.50), with a larger number of weak associations between individuals (Association Index<0.50).The numbers around the circumference of the sociogram represent individual Irrawaddy dolphins.

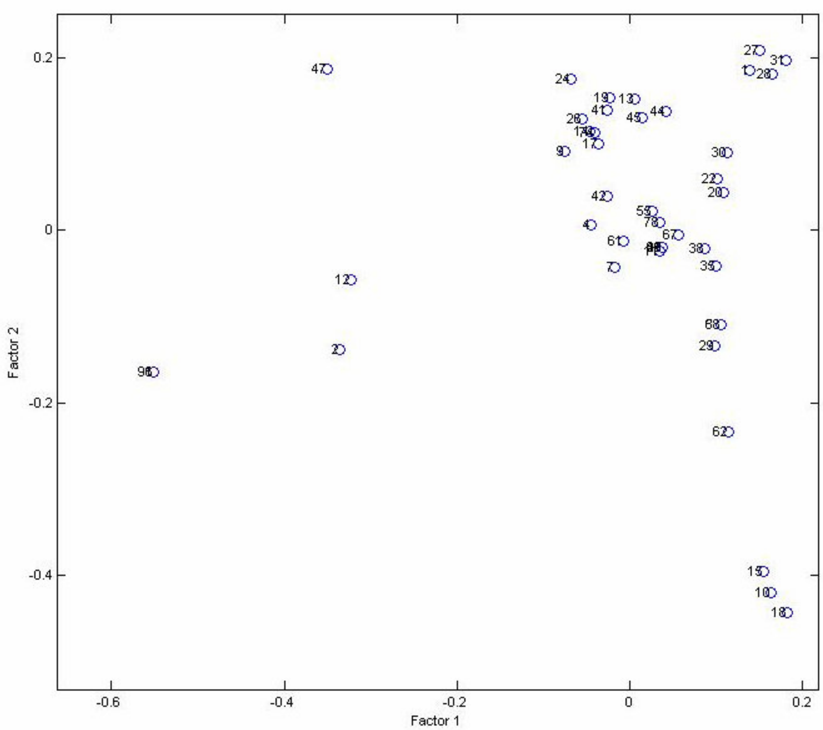


Figure 8.9. Principal Component Analysis illustrating the association between individual Irrawaddy dolphins in Chilika Lagoon. While some individuals did not associate with any other individuals, some individuals formed clusters with other individuals. Dolphins from the South-Central Sectors formed a cluster in the lower right corner suggesting some relationship between location and social structure.

8.4. Discussion

Habitat Preference

Irrawaddy dolphins in Chilika use waters between 1-3m deep (75% of observations) (Figures 8.4) and salinity between 2-40ppt (Figures 8.5). The results are generally within the range reported for the species, although the minimum depth is less than previously recorded. All the Irrawaddy dolphin locations recorded from Songkhla Lagoon in Thailand (of similar depth profile to Chilika Lagoon) were also from relatively deep sections (2-4m) of the Lagoon (Kittiwattanawong et al. 2007). As stated in Chapter 3, coastal populations of the species have been recorded from waters ranging from 7.5-20m deep, but riverine populations apparently prefer deeper (40m in the Mekong River and 110m in the Ayeyarwaddy River) rather than shallow areas (Smith & Hobbs 2002; Beasley 2008 ; Smith et al. 2006). The limited information available regarding the species indicates that Irrawaddy dolphins can exploit waters of varying water depth and salinity. In Chilika Lagoon, factors like water clarity or prey availability may help explain the patterns of habitat use but were beyond the scope of this study.

Habitat use

Foraging, milling and socializing dominate the activity budgets of the dolphins in both the Outer Channel and the South-Central Sector during daylight hours in the dry season, with core areas being major feeding grounds for dolphins both in the Outer Channel and South-Central Sectors (Figure 8.2, 8.3). The number of times dolphin groups were found feeding in the Outer Channel was significantly higher than in the South-Central region. However, these spatial differences are potentially confounded by group identity (Figure 8.9).

The current distribution and habitat use by dolphins in the Lagoon could reflect their historical distribution in the Lagoon, as well as adjustments to any changes in distribution and density of prey. As discussed in Chapter 3, Chilika Lagoon is a highly productive system that is rejuvenated every wet season with nutrients from river beds and sea mixing (Ghosh et al. 2006). Historically the Lagoon had two openings to the sea, the old sea mouth at Arakhuda in the northeast and another old sea mouth in the southeast at Palur (Chapter 2 Figure 2.2). Both entrances allowed large influxes of nutrients and fish into the Lagoon, making Chilika a highly suitable habitat for Irrawaddy dolphins. Fish catches have declined since early 1980s prompting the dredging of a new sea mouth at Satpada (Chapter 3), which is only 1.5km away from the present core area of the dolphins. The new mouth currently allows fish to be transported directly from the sea into the Outer Channel. The South-Central Sector presently depends mainly on the fish from the Outer Channel being distributed in the Lagoon. This situation could explain the differences in the proportion of time dolphins spent milling and feeding in the two areas, with dolphins in the Outer Channel core area having access to more plentiful prey than animals in the South Central Sector, which accordingly need to spend more time searching for prey than feeding. This information suggests that currently, the Outer Channel is the major feeding ground for the population of Irrawaddy dolphins in Chilika and requires management that sustains prey availability.

Group Size

In Chilika Lagoon, group sizes of Irrawaddy dolphins are small, averaging 3.5 animals per group. The average group size is comparable to data from other studies of the species from riverine and lagoonal habitats (Smith & Jefferson 2002; Beasley, 2008; Smith et al 2006). The average size of Irrawaddy dolphin groups in the Ayeyarwady River is 2-3 dolphins (Smith & Tun 2007a), in the Mahakam River 4-5 dolphins (Kreb et al. 2007) and in the Mekong River 6-7 dolphins (Beasley et al. 2007). Group size information is not available for the Irrawaddy dolphin population from Songkhla Lagoon, Thailand. Australian snubfin dolphins from two Bays in North Queensland generally occur in slightly larger schools of average size 5-6 dolphins (Parra 2005).

The distribution of group sizes for Irrawaddy dolphins in Chilika is skewed towards smaller groups of 1-3 dolphins. Most avian and mammalian species show a similar pattern. Few groups are large and very few are extremely large, whereas most are small (Reiczigel et al. 2008; Krause & Ruxton 2002). Ecological and social factors can influence group sizes. The type and availability of prey, competition among individuals, predator avoidance, proximity to 'safe' areas, group composition, social interactions, and environmental factors, like visibility, temperature and time of day can all influence group size in different species leading to different social systems (Elgar 1989; Chapman et al. 1995). Regions with low food supply generally support small groups of animals which reduces intraspecific competition (Wrangham et al. 1993). Smaller group sizes thus may indicate: a) limited or constrained food supply, or b) a trade-off between increased food intake, reduced intraspecific conflict and increased risk from predators. For Irrawaddy dolphins in Chilika Lagoon, small group size is advantageous as it would increase fitness from dispersed feeding over patchy resources.

Qualitative data from fishers in Chilika (Chapters 2, 4, 10) suggest that fish catches are both unstable and declining over the past 15 to 20 years. Fish enter the lagoon via the Outer Channel making this region a richer source of food for dolphins and fishers alike. Accordingly, my group encounter rates with Irrawaddy dolphins in the Outer Channel of Chilika Lagoon were higher at 0.78 dolphins/hour than in the South-Central Sector (0.12 dolphins/hour, Chapter 6). The prominent form of fishing in the Outer Channel uses fixed fish and shrimp traps (Appendix E), and dolphins are seen to feed from the lead lines of these nets in groups of two or three animals. The study of relationships between dolphin group size and density with prey type and density may better explain average group sizes and habitat use but was beyond the scope of this study (although is currently being studied, Nachiket Kelkar personal communication).

The small group sizes of Irrawaddy dolphins in Chilika Lagoon may also suggest a predator avoidance strategy using diffusion rather than aggregation (Connor & Heithaus 1996). A negative correlation between group size and vigilance behaviour has been reported for more than 50 species of animals (Elgar 1989). In Chilika Lagoon, some species of sharks, sting rays and larger delphinids have been reported entering Chilika Lagoon via the new sea mouth (personnel communication with fishers from Aluptana Village, who catch most large sharks entering Chilika Lagoon before they enter the core area of the dolphins). Sting rays have been known to kill Irrawaddy dolphins in the Outer Channel of the Lagoon (personal communication with fisher from village Alupatna). No reports of mortalities of Irrawaddy dolphins from interactions with larger delphinids which visit the Lagoon are available. Anthropogenic risks to dolphins include the presence and density of motorized boats which is high in the Outer Channel and fishing nets like drift nets, large size gill nets and trammel nets (Chapter 3). While feeding in the Outer Channel, dolphins face risks from these fishing gears, disturbance of tourist boat traffic and possibly shark predation. It was beyond the scope of the study to analyze how the dolphins perceived these various risks and if these risks affected group sizes and behavior.

Social Structure

The preliminary analyses of social structure using cluster analysis, Principle Component Analysis and sociograms for Irrawaddy dolphins in Chilika Lagoon suggested that of the 48 individuals analyzed, some individuals did not associate with any other individuals, a few individuals formed clusters of two individuals (14 individuals had an association index ≥ 0.5) and these individuals associated loosely with other individuals in the population. Most individuals in Chilika had weak associations within the population. The Principal Component Analysis suggested that social organization is related to spatial distribution. Strongly associated individuals from the South–Central Sector of Chilika were plotted far away from clusters and loosely associated individuals in the Outer Channel (Figure 8.9).

All these analyses suggest that Irrawaddy dolphins in Chilika Lagoon live in a fluid society, unlike their conspecifics in the Mahakam River and Mekong River and the closely related Australian snubfin dolphin from Cleveland Bay, Australia. The two riverine Irrawaddy dolphin subpopulations differ from that in Chilika Lagoon in terms of habitat size, habitat type and availability. The riverine population of Irrawaddy dolphins in the Mekong lives in four stable subpopulations each of which occupies one or more deep pools throughout the dry season. Associations within each subpopulation are thus inevitably strong. In Cleveland Bay, Australian snubfin dolphins are found at low density in open coastal waters where they are at risk from predators like tiger sharks. Stable, structured groups of 5-6 animals may assist in predator avoidance. In Chilika Lagoon, more than 60% of the population is found in smaller groups of 3-4 animals at high density in the Outer Channel (Figure 2.2). These inter-population comparisons suggest that in addition to prey availability and predator avoidance, the spatial arrangement of feeding habitats also influence the social structure of *Orcaella*.

Survey methodology (surveys instead of focal follows) can influence the results of the social analysis (Gibson & Mann 2009). Surveys tend to produce small sample sizes, thus giving a relative idea of social structure, while focal follows can provide temporal details at the individual level. The spatial distribution of dolphins in Chilika with more than 60% of the population found in a small area requires a longitudinal study with more detailed focal sampling to represent clearly the complexity in social structure. A combination of survey and focal sampling along with genetic sampling would thus be ideal to separate the influences of space availability, prey availability, predator avoidance, kinship and sampling methods on social organization for future assessments of Irrawaddy dolphins in Chilika.

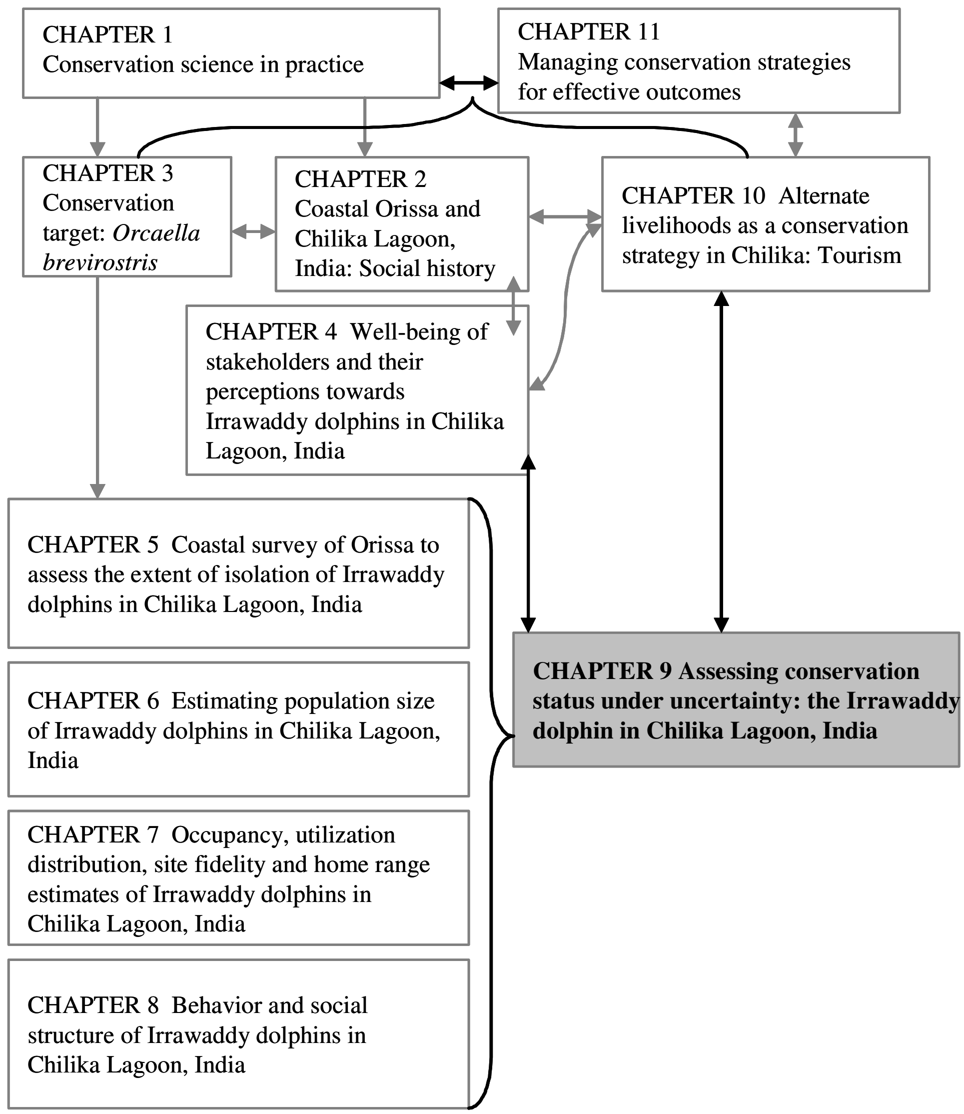
8.5. Chapter Summary

- Grouping behavior and social structure of a population have important implications for conservation and management. The variability within cetacean species makes population-level studies important to understanding ecological aspects of social evolution.
- Average group sizes of Irrawaddy dolphins in Chilika Lagoon did not show significant change between feeding, milling and traveling, but increased significantly during socializing and resting behaviors.
- The overall behavior of Irrawaddy dolphins in Chilika Lagoon was dominated by feeding, milling and socializing. The two core areas differed significantly in the proportion of groups milling and feeding, with a larger number of groups feeding in the Outer Channel.
- Dolphins were found across the entire range of water depths and salinity in the Lagoon. Group sizes were weakly correlated with environmental variables.
- A large percentage of the population studied exhibited only weak social bonds. Only 14 of the 48 individuals studied showed strong associations with one or more

identified individuals, suggesting a fluid society with fission-fusion type of relationships.

- The social structure of Irrawaddy dolphins in Chilika Lagoon differs from the other studied populations of this species, which all show highly-structured societies with constant companions and casual acquaintances
- Further investigations on the social and ecological factors influencing group sizes, distribution and habitat for the Irrawaddy dolphins would provide further insights into the potential role of behavioral ecology in the conservation of this species.

9 ASSESSING CONSERVATION STATUS UNDER UNCERTAINTY- THE IRRAWADDY DOLPHIN IN CHILIKA LAGOON, INDIA



In this chapter, I review the information from Chapters 2 through Chapter 8 and assess the subpopulation of Irrawaddy dolphins in Chilika Lagoon using The World Conservation Union (IUCN) criteria for classifying threatened species. The Red List category is expected to reflect the extinction risk faced by a population. I use two methods: the conventional IUCN Red List protocol and the RAMAS Red List software at the regional level. I deal with different types of uncertainty by making them transparent and incorporating them into the assessment using RAMAS. The chapter presents the differences between the two methods of assessment and discusses the limitations of both methods for small populations. I then discuss the drawbacks of utilizing the Red List category for deciding priority conservation measures for Irrawaddy dolphins in Chilika.

9.1. Introduction

Status assessments play a key role in determining a range of conservation policies and practices: identifying the type of conservation strategy required; prioritizing resource and funding allocations, designing monitoring programs, and finally informing management decisions. The importance of these matters makes the quality and quantity of data used for assessments and the assessment *per se*, matters of vigorous critique and continuous refinement. The IUCN (1994, 2001, 2003, 2004, 2006) offers the standard and most widely applied protocol to assess the conservation status of species at both global (Mace & Lande 1991) and regional scales (Gärdenfors 2001), and this approach is mandated in many jurisdictions. Population structure, generation length, age class survival probability, mortality and fecundity are just some of the life history parameters required to produce robust viability models for a comprehensive assessment. Of the 129 marine mammal species, 38% are Data Deficient (Schipper et al. 2008). Small and local populations often remain at risk of sudden extinction with data deficiency being both a cause and consequence of this risk. In other cases, where the population is naturally small and causes of unnatural mortality are minimal or controlled, risk assessments can lead to conclusions which are overstated or misleading as a result of the uncertainty in the available data.

The two main types of uncertainties (Table 9.2) faced by ecologists and managers are epistemic (measurement related uncertainty) and linguistic (definition related uncertainty) (Regan et al. 2002). While epistemic uncertainty is reduced by improving sampling and analytical tools, linguistic vagueness in definitions and concepts are incorporated as differing social attitudes. Attitudes towards a definition, a process, a question or a problem, can influence the degree of uncertainty and challenge acceptable to conservation managers. Identifying and coping with these uncertainties can help design ways to address them in the future.

The IUCN Red Listing process assesses risk to extinction based on thresholds or cut-off values for five quantitative criteria. If any one of the criteria is met, the particular taxon can be Red Listed. It is considered advisable to evaluate the taxon against every criterion and sub-criterion before reaching a conclusion. The method deals with uncertainty by providing ranges and 95% confidence interval values. Following the precautionary principle, the lower values are compared with cut-off values to deal with uncertainty, when assigning a taxon to any one of three threatened categories: Critically Endangered, Endangered or Vulnerable, in accordance with the precautionary principle. The criterion which gives the highest category of threat is given priority for the final listing and the assessments against the other categories are listed in the documentation, which provides all the necessary information required for an assessment to prove the validation of the final categorization. The five criteria on which this categorization of risk is based are listed in Table 9.1 The details of the IUCN 2007 Red List criteria and sub criteria along with the guidelines on its usage are available on the IUCN Red List website (www.iucn.org).

Table 9.1. Comparing the two methods used- IUCN Red List criteria and the RAMAS RedList software

IUCN REDLIST CRITERIA →	RAMAS REDLIST
Criteria A. Population Reduction Criteria B. Geographic Range Criteria C. Small population size and decline Criteria D. Very small or restricted population Criteria E. Quantitative analysis (NA)	1. General information 2. Ecology 3. Population(of mature animals) 4. Extent and Area of Occurrence 5. Population reduction 6. Fragmentation 7. Risk (NA) 8. Attitudes
Uncertainty represented as a range of plausible values for a particular quantity	Fuzzy sets used to propagate uncertainty from input data (triangular or trapezoidal numbers)
OUTCOME: threat category based on decision rules and threshold values	OUTCOME: threat category based on making uncertainty explicit

The RAMAS RedList (Akcakaya & Ferson 1999) software was designed in 1999 within the framework of the Red List Criteria (IUCN 2006c). The program has the ability to propagate uncertainty distributions around Red List Criteria threshold values, using ‘fuzzy’ arithmetic. This approach generalizes the IUCN rules by accepting fuzzy intervals and triangular/trapezoidal fuzzy numbers as inputs to represent empirical estimates of unknown quantities. Fuzzy numbers can be considered as a set of nested intervals at each of many levels between zero to one. These levels correspond to the vertical axis in the graphical representation of a fuzzy number. RAMAS RedList uses level-wise operations on the intervals that compromise the fuzzy numbers. Thus, the interval operations are repeated at all levels to define the fuzzy operations (Akcakaya et al. 2000). The resulting fuzzy IUCN classification includes two pieces of information: the conservation category to which a species belongs, and the degree to which it belongs in that category. The software also offers an option of including values of various social attitudes towards the parameters used in the assessments in the form of 'Dispute Tolerance', 'Risk Tolerance' and 'Burden of Proof'. 'Dispute Tolerance' is based on the notion of developing a fuzzy number using the opinions of a group of experts, each of whom may have a different idea about the value of a particular parameter, for instance, trend in population size. A compromise between the extremes of complete inclusion and complete consensus is represented by a Dispute Tolerance value of 50%. Burden of proof is a quantified attitude of the assessor towards the meaning of absence of evidence. It relates the perception of risk to uncertainty regarding the best estimate or central tendency of risk data. Risk Tolerance of lower than 50% corresponds to a precautionary attitude, and greater than 50% corresponds to an evidentiary attitude. For example, a precautionary attitude would accept a species as safer than endangered only if the assessor is quite sure that it is not endangered while an evidentiary attitude would demand substantial evidence of endangerment before allowing such a classification. 'Burden of Proof' is thus linked to 'Risk Tolerance' and helps determine the middle point in the range of categories. These attitudes can be those of local community leaders, stakeholders, experts or the assessors alone.

By assessing the status of the *Orcaella* subpopulation in Chilika using both the Red List Criteria and the RAMAS software (Table 9.2), I demonstrate both limitations and benefits of these processes, and reiterate the importance of species specific life history studies for robust assessments and pragmatic conservation action.

Table 9.2. The various sources of epistemic and linguistic uncertainty with their most appropriate general treatments. The references related to the suggested treatment are provided in the text

Source of uncertainty	General treatments
Epistemic uncertainty	
Measurement error	Statistical techniques; intervals
Systematic error	Recognize and remove bias
Natural variation	Probability distributions; intervals
Inherent randomness	Probability distributions
Model uncertainty	Validation; revision of theory based on observation; analytic error estimation (for metamodels)
Subjective judgment	Degrees of belief; imprecise probabilities
Linguistic uncertainty	
Numerical vagueness	Sharp delineation; supervaluations; fuzzy sets; intuitionistic, three valued, fuzzy, paraconsistent and modal logics; rough sets
Nonnumerical vagueness	Construct multidimensional measures then treat as for numerical vagueness
Context dependence	Specify context
Ambiguity	Clarify meaning
Indeterminacy in theoretical terms	Make decision about future usage of term when need arises
Underspecificity	Provide narrowest bounds; specify all available data

9.2. Methods

9.2.1. IUCN Red List and RAMAS RedList®

I summarize the general information and ecology of the taxon *Orcaella*, and then incorporate the data for: a) population size based on Mark-Recapture estimates and minimum population size N_{min} (Chapter 6) (Wade 1998), b) population reduction based on mortality rates (Chapter 3), and c) Extent of Occurrence and Area of Occupancy (Chapter 7). I then evaluate the data against the IUCN and RAMAS RedList criteria. Theoretically, sound sampling and analytical protocols were used to estimate the parameters for the assessment, thus reducing the degree of uncertainty in the final assessment. I did not carry out a quantitative analysis such as a population viability analysis (PVA), and therefore did not include 'Risk' or 'Criterion E' in the assessments. A robust PVA requires data on life history parameters (sex ratios, reproductive rates and age distribution) that are not available for *Orcaella* (Chapter 3).

9.2.2. Data Collection

9.2.2.1. General Information

Orcaella brevirostris was assessed as Data Deficient (DD) at the global scale in 1996 by the IUCN, and this assessment still stands (Chapter 3). Several isolated populations have been listed as Critically Endangered (CR) (Table 9.3): Mahakam River (IUCN 2000), Mekong River (IUCN 2004), Ayeyarwady River (IUCN 2004), Songhkhla Lake (IUCN 2004) and Malampaya Sound (IUCN 2004).

Table 9.3. IUCN Red List assessments of isolated populations of *Orcaella brevirostris* from the species range. Chapter 3 provides details of abundance and associated CVs.

Population	IUCN Status	Year assessed	Best population estimate
GLOBAL	DD	1996	
Ayeyarwady River	CR C2a (i, ii); D	2004	59
Mahakam River	CR D	2000	33-50
Malampaya	CR C2a (i, ii); D	2004	77
Mekong	CR C2a (i, ii); D	2004	69
Songhkla	CR C2a (i,ii); D	2004	< 50
Chilika	DD	-	

9.2.2.2. Ecology and Life History

As described in Chapter 3, Irrawaddy dolphins grow to a maximum length of 2.25m; intercalving interval, social structure and calving rate are unknown for the species. One individual in Chilika Lagoon was seen with a new calf in January of both 2007 and 2009, suggesting that intercalving interval can be two years (personal communication Nachiket Kelkar and Coralie D'Lima) but a much larger sample size is required as a basis for robust conclusions. The estimated age of sexual maturity is nine years and the estimated oldest age of a reproducing female is 28 years for the genus (Marsh et al. 1989; Arnold 2002). Generation length, defined as the average age of parents of the current cohort or average age of reproducing adults in the population is unknown for the species and for the population in Chilika. Considering the lack of life history data, I used fuzzy numbers for generation length based on other delphinids occupying similar ecotypes and to estimate population reduction in section 9.2.1.4 (Taylor et al. 2007a).

9.2.2.3. Population Size

In the absence of longitudinal data or information from a carcass study, it is difficult to estimate the proportion of reproductively-mature individuals in a population as is required for an IUCN assessment. I assumed the proportion of mature individuals is 53% of the total population size based on information for a similar sized cetacean species – *Sotalia fluvialatis* (Taylor et al. 2007a), occupying a similar ecotype (Kreb et al. 2007). The estimates for total population size (Chapter 6), and total number of mature individuals in Chilika are summarized in Table 9.4. Assuming 53% of the total population size was mature, I estimate a total of 56-74 mature individuals.

Table 9.4. Total number of mature individuals in the population estimated as 53% of total population size of Irrawaddy dolphins in Chilika lagoon, India. The total population size was estimated from Mark-Recapture Analysis in Chapter 6.

N	Number of mature individuals
111	58
95	50
107	56
140	74
109	57
112	59

9.2.2.4. Population Reduction

Available data on mortality from 2003-2006 indicate that an average of eight animals died annually (Chapter 3). These deaths include both natural and unnatural mortality giving a crude estimate of a 7% mortality rate, based on estimated total population size (Chapter 3). I calculated survival in the population using $S=Sr^{3\,(G)}$

where

Sr is the present rate of survival

G (Generation time) = 7 or 10 years (I used both values to incorporate uncertainty)

In the IUCN Red List, Criterion A deals with population reduction, the general span of time during which a given threshold reduction is measured, and is the longer of ten years or three generations for a species. I used a range of present survival rates (0.92, 0.94 and 0.96) to calculate percent population reduction (Sr-S)*100. I estimated that current mortality rates will lead to more than 50% of the population dying in three generations. Table 9.5 provides the range of survival rates and percent population reductions for generation times of both seven and ten years.

Table 9.5. Percent population reduction in three generations at different values of generation times (G=7 & 10 years) and survival rates (S_r=0.92, 0.94, 0.96).

Generation time	% population reduction in 3 generations
G=7 ; Sr=0.92	74%
G=7 ; Sr=0.94	66%
G=7 ; Sr=0.96	53%
G=10; Sr=0.92	87%
G=10; Sr=0.94	80%
G=10; Sr=0.96	66%

9.2.2.5. Area and Extent of Occurrence

The estimates of Area of Occupancy and Extent of Occurrence were calculated in Chapter 7. The Extent of Occurrence was estimated using simple convex hulls and excluding areas of islands, mainland and regions of the Lagoon too shallow for dolphins to occupy. To calculate the Area of Occupancy or core habitat, I used the α Hull application (Burgman & Fox 2003) which is a generalization of convex hulls. I estimated the Extent of Occurrence as 308 km^2 to 330km^2 and the Area of Occupancy as 131km^2 to 195 km^2 for study period 1 (November 2004 to May 2005), study period 2 (November 2005 to May 2006) and for both study periods pooled together.

9.2.2.6. Fragmentation

The surveys carried out by the Chilika Development Authority (Pattnaik et al. 2007) indicate that the dolphins are present in the Lagoon throughout the year. My results also confirm that the population uses the Lagoon between the months of September and May with high levels of site fidelity for certain regions (Chapter 8). Coastal surveys indicate that the population in Chilika is geographically isolated (Chapter 5).

9.2.2.7. Social Attitudes

I used the attitude options to examine the effect of opinions on the risk assessment for the population in Chilika. I kept Dispute Tolerance as neutral (50%), Risk Tolerance as slightly precautionary (45%) and Burden of Proof slightly threatened (45%). My reasons are summarized below.

Given the results of my research on the dolphins' space use and habitat availability from Chapter 7 and 8, I conclude that maintaining habitat quality and size is imperative for the persistence of the population. I also obtained a range of subjective opinions regarding habitat quality, socio-economic well being, trends in fish and dolphin abundance. From Chapter 4, it is evident that the local fishers in Chilika perceive the population size of dolphins and their distribution range to be decreasing. Although there is little or no contention over the issue of past mortality figures, local government figures since 2005 suggest that the Irrawaddy dolphin population is increasing in size. To consider both these rather contrasting viewpoints, I decided to keep Dispute Tolerance at 50%.

As the assessor, I maintained that the Burden of Proof and Risk Tolerance of my data set needs to be more precautionary rather than neutral given that the Potential Biological Removal value of 1 animal per year as estimated in Chapter 6. I used this information along with the information on current threats facing the dolphins in Chilika, as the rationale for setting the Burden of Proof and Risk Tolerance of my data set at slightly precautionary (45% instead of neutral at 50%).

9.3. Results

9.3.1. IUCN Red List and RAMAS RedList

Based on the conventional IUCN process, the Chilika subpopulation of *Orcaella brevirostris* would be listed as Critically Endangered if lower estimated/projected values are assessed against the cut-off values set for Criteria A and D (Table 9. 6). RAMAS also classified the subpopulation as Critically Endangered with plausible categories being Critically Endangered and Endangered, based on contributions from all available data, but also when exclusively based on the data for Criterion A. I used the attitude option to examine the effect of attitudes on the conservation status of the population. Keeping Dispute Tolerance neutral (50%), Risk Tolerance slightly precautionary (45%), and Burden of Proof slightly threatened (45%), the population was also classified as Critically Endangered [A2abcd]. Plausible categories included Critically Endangered and Endangered (Figure 9.1).

Table 9.6. Status assessment of Irrawaddy dolphins in Chilika Lagoon based on the cut-off values of the IUCN Red List Criteria A, B, C and D

Criteria / Category	**A**	**B**	**C**	**D**
CR	G=10 **CR A4(abcd)**		CR <250 mature Continuing decline?	<50 mature **CR d1**
EN	G=7 **EN A4 (abcd)**	**EN B1** EOO<5000km^2 **EN B2ab(iii,iv)** AOO<500km^2		<250 mature **EN d1**

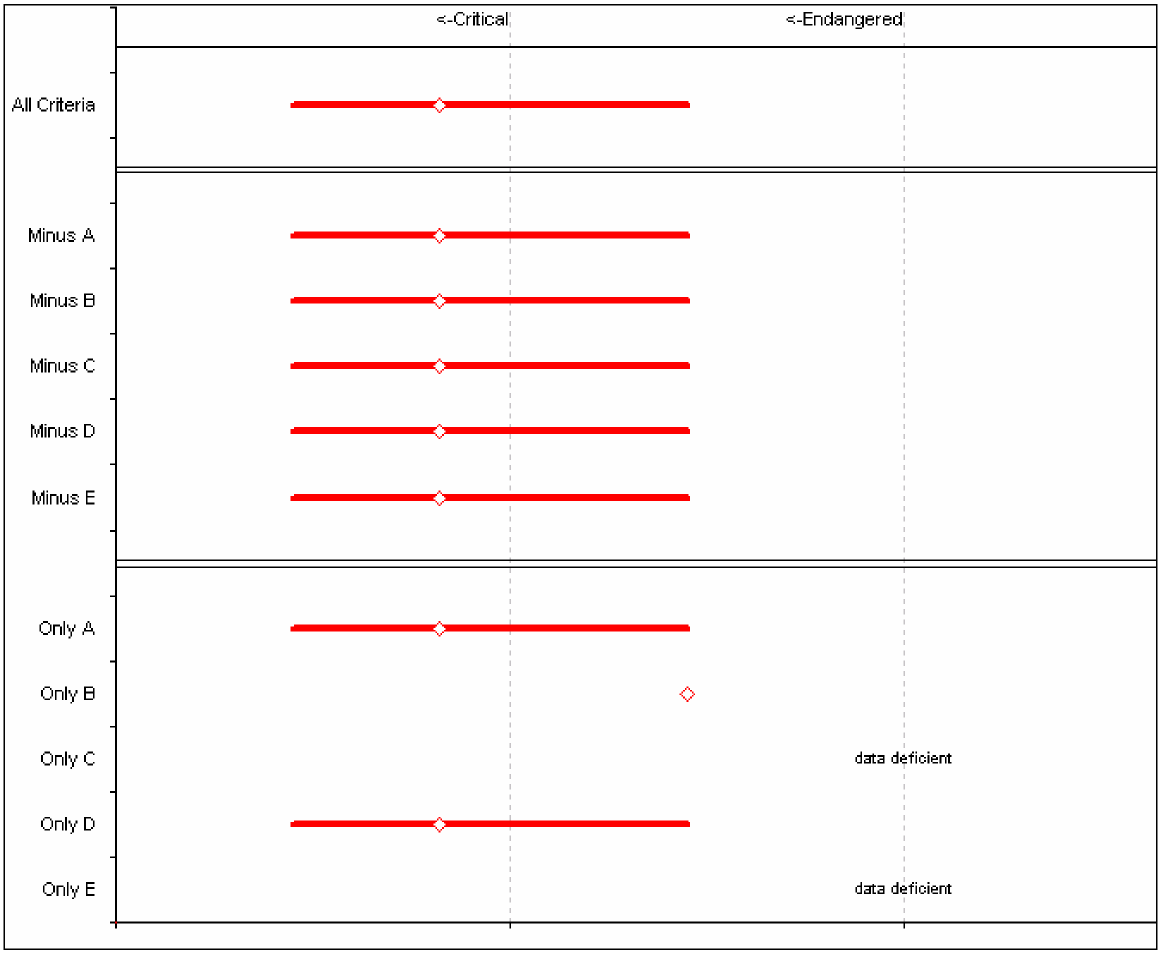


Figure 9.1. Status assessment of the Irrawaddy dolphin population using RAMAS software with the added options of incorporating attitudes.

9.4. Discussion

The conventional IUCN assessment and the RAMAS Red List assessment suggest that the population of Irrawaddy dolphins in Chilika Lagoon should be listed as Critically Endangered. This decision would be precautionary rather than evidentiary, but not without uncertainty. The logical management response would be to classify the population as Critically Endangered. Following a conventional 'preservationist' approach, this assessment would lead to a conservation intervention such as the classification of core dolphin areas in the lagoon as a dolphin sanctuary, or a no fishing zone. This option was proposed by Chilika Development Authority in July 2005 and was met with resistance from local communities at Satpada (Kalpavriksh 2005) and led to a protest in 2005 (personal communication with village elders). Chilika already has a protected area of 1km^2 for migratory birds in the South Central Sector, which is completely closed to fishing for four months every year, and local people are wary of further exclusion of local communities from their traditional fishing grounds.

Especially, in developing countries like India, management decisions for successful species conservation will depend largely on policy incorporating both social and ecological studies. Therefore, risk assessments need to be objective and as evidentiary as possible, if they are to be the basis for decision makers and conservation action. Risk assessments should be able to delineate the primary causes of threat and extinction risk, because it is common practice to base conservation priorities on an IUCN assessment (Gärdenfors 2001) even though the IUCN warns against this approach. It would be desirable for the criterion by which a species or a population is listed as threatened to highlight the major threats, thus reinforcing the conservation potential of the IUCN Redlisting process. Conservation practitioners would then have a rationale for implementing appropriate strategies to conserve a species, rather than funneling all available resources into population monitoring that merely document population change in a population rather than attempt to conserve it *per se*. Whenever possible conservation action should address all the anthropogenic threats facing the species *and* the ecosystem, especially in the face of the uncertainty resulting from climate change and changing economic priorities.

Although uncertainty is ubiquitous in scientific research, representing it and treating its source is important to avoid misleading conclusions. The formal processes presented here identify some of the sources of uncertainty which I further discuss. The absence of data on population structure, and life history of *O. brevirostris* is a major source of uncertainty precluding an accurate 'quantification' of risk using population viability models. In India, *Orcaella brevirostris* is listed as a *Schedule I* species under *The Wildlife (Protection) Act of India 1972* (Anonymous 2006).*Schedule I* species are given the highest order of protection under the Ministry of Environment and Forests. Given the importance of the species, and the financial and logistical resources available to assess life history characteristics from carcass salvage programs, it is surprising that the population remains Data Deficient in terms of life history parameters. Absence of such vital data is a common impediment to evidence-based conservation in India, and the whole of Southeast Asia (Sodhi 1999; Bawa et al. 2004; Madhusudan et al. 2006; Bawa 2006b).

Comparing the two assessment processes and their results demonstrated the limitations and opportunities of both processes. The IUCN Red List Criteria is limiting because of the sharp demarcations between the definitions of the different threat categories (Akcakaya et al. 2000; IUCN 2003). These sharp demarcations are problematic when both epistemic (measurement related) and linguistic (vagueness) uncertainty exist (Regan et al. 2000; Regan et al. 2003). If a taxon lies on the borderline between two categories, the worst case scenario or the lowest estimate is given priority. Using an evidentiary attitude, one can argue that 'Data Deficient' taxa cannot be assessed, an excuse for being given low priority for conservation action. RAMAS offers an alternative, logical albeit abstract solution to the problem by using the sharp boundaries set by the IUCN as midpoints around which data are presented (Regan et al. 2000). Prior selection of the lower value of estimates is not required in RAMAS. The inclusion of uncertainty in social attitudes provides a means of dealing with contentious issues and thus helps develop an unbiased final decision. By incorporating both uncertainty in numbers and attitudes, RAMAS provides a range of categories, estimating the degree to which a particular assessment reflects the true status of the species.

The size of Chilika Lagoon is approximately 800km^2 to 1000km^2 . Historically Irrawaddy dolphins in Chilika lagoon were known to use parts of the Northern Sector of the lagoon (Chapter 4). Presently, less than 330km^2 of the lagoon is used by the dolphins, of which they mostly use less than 120 km^2 (Chapter 7). Further decrease in the area of suitable habitat is likely to increase interaction between dolphins and motorized boats, and fishing gear, thus increasing the threats to dolphins (Chapters 4, 10). In the IUCN Red listing process, Criterion B (Geographic Range-including Extent of Occurrence and Area of

Occupancy) highlights the risk from decreasing habitat. But, following IUCN rules, my assessment of the taxon was not based on Criterion B as the focus for conservation action, thus inadvertently downplaying this threat. Even though the dolphin population is listed on the basis of its population size and past decline, sustaining the population at its present size without managing the habitat and its resources will be impossible.

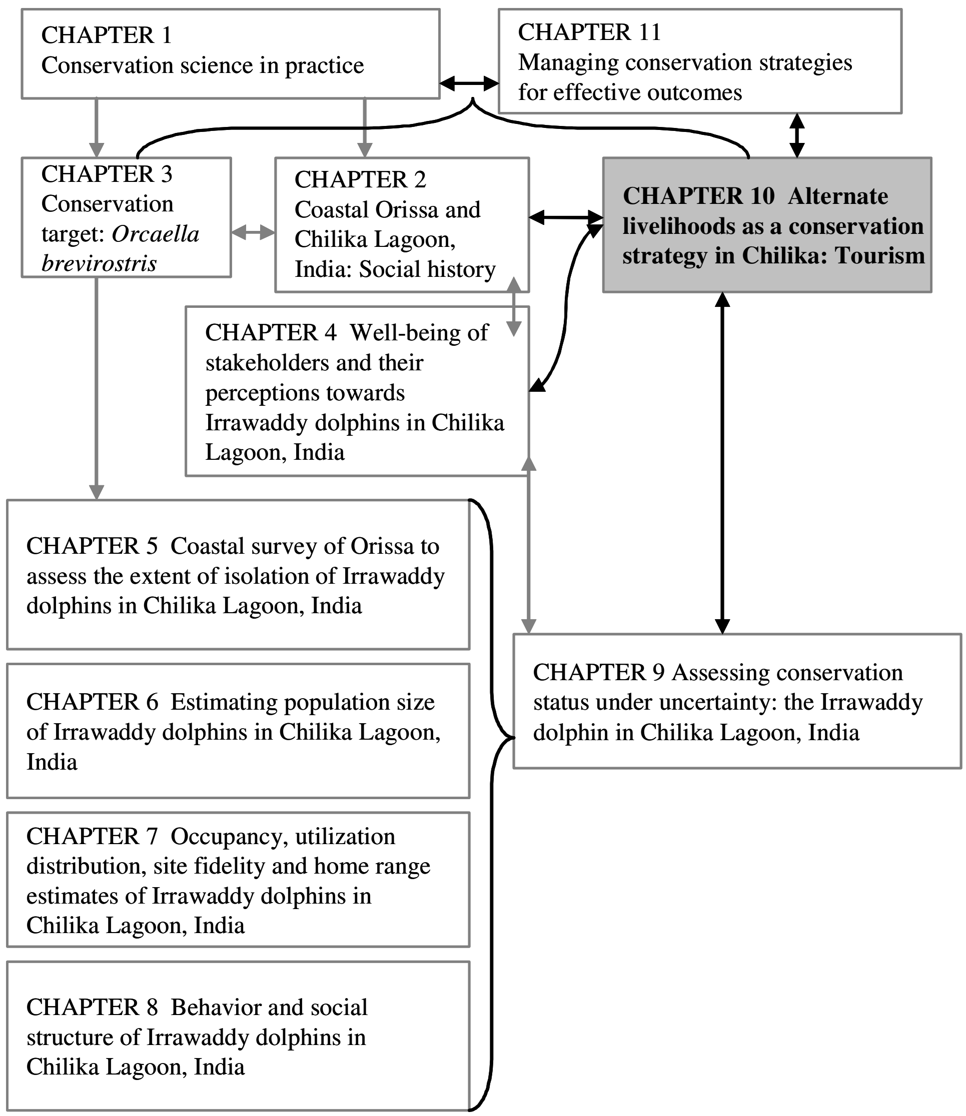
The Montreux Record (RAMSAR 2008) is a register of wetland sites on the List of Wetlands of International Importance where changes in ecological character have occurred, are occurring, or are likely to occur as a result of technological developments, pollution or other human interference. The shrinkage of Chilika Lagoon from siltation (Chapter 2) and large scale aquaculture caused the Lagoon to be placed in the Montreux Record from June 1993 to November 2002. Qualitative information regarding the historical distribution of dolphins (Chapter 4) suggests that changes in distribution of dolphins in the Lagoon may be related to physical changes in habitat. Chilika was removed from the Montreux Record (RAMSAR 2008) on November 11th 2002 after the new mouth was dredged to allow the flow of sea water into the lagoon. The physical changes in the lagoon have been large and varied, and have, in turn, changed the regime of fish distribution, fishing intensity and distribution, and fish catch – amount and diversity. However I am aware of no evidence that suggests that there have been consequential changes to the distribution of the dolphins in Chilika.

Andrewartha and Birch (1954) stated that ‘there is no fundamental distinction to be made between the extinction of a local population and the extinction of a species, other than this that a species becomes extinct with the extinction of last local population’. The risk of local extinction is high in species like Irrawaddy dolphins, which are top-level predators with slow reproductive rates (Purvis et al. 2000). Risk assessments at the level of the local population are thus indicative of future global status and require due attention as conservation planning targets.

9.5. Chapter Summary

- The World Conservation Union (IUCN) Red List protocol is the accepted system of categorizing risks of extinction at a global scale and is designed to reflect extinction risk probability at that scale.
- The IUCN Red List criteria are precautionary in the way they deal with uncertainty, whereas the RAMAS RedList provides the user with the opportunity to incorporate uncertainty, particularly, uncertainty in social attitudes providing a more comprehensive risk assessment.
- IUCN Redlist criteria and the RAMAS RedList software both categorize the Irrawaddy dolphin population in Chilika lagoon as Critically Endangered.
- Both methods list the population of dolphins based on criterion A, that of population size and reduction. However, given the history of Chilika and data on space use, habitat size and quality remains an important source of risk to the population.
- The drawback of utilizing the rationale of the Red List categorization for deciding priority conservation measures for Irrawaddy dolphins in Chilika is that this approach potentially downplays the importance of habitat size and quality.

10 ALTERNATE LIVELIHOODS AS A CONSERVATION STRATEGY: DOLPHIN TOURISM IN CHILIKA LAGOON, INDIA



In this Chapter I explore the human dimensions of dolphin conservation in Chilika Lagoon and the community-introduced alternate livelihood of dolphin watching tourism in the Outer Channel of Chilika. I describe the functioning of the tourism industry and its importance to the local community. I assess the social perceptions of community members involved in this industry towards dolphins, natural resources and tourism. I explore locally-perceived sources of stress and mortality to dolphins and the immediate solutions suggested by local stakeholders. The results are assessed for their potential to help design future co-management programs for conserving dolphins and sustaining livelihoods from dolphin tourism. I discuss the complexities of the tourism industry in Chilika. The chapter thus explores the scopes and limitations of various strategies that can be used to conserve Irrawaddy dolphins in Chilika.

10.1. Introduction

Nature-based tourism is growing rapidly in both developed and developing countries as a form of sustainable livelihood (Gossling 1999;Tao & Wall 2009). Nature-based tourism has considerable potential as an incentive strategy to achieve conservation goals (Salafsky & Wollenberg 2000). Protected areas and flagship species (e.g., large terrestrial carnivores, whales and dolphins) are a focus for a large percentage of nature-based tourism. Forty-four communities from 12 countries have been recorded to benefit from whale watching in south and south-east Asia (Hoyt 2001). Eighty seven countries and 495 communities are known to earn income from the whale watching industry (Hoyt 2001; Hoyt 2005). All these communities are close to populations of cetaceans that are continuously accessible or whose seasonal presence in the focal area is predictable.

Whale-watching encompasses all cetaceans (whales and dolphins) and is defined as ‘any commercial enterprise that provides for the public to see cetaceans in their natural habitat’ (International Whaling Commission, 1994). In most developed countries, whale and dolphin watching industries are strictly regulated, with limited access and requirements to follow strict Whale-watching Guidelines or Codes of Conduct for tourist vessels around whales (Donoghue 1996; Constantine 1999). Such systems are typically not yet in place in developing countries. A whale/dolphin watching industry with no limit on access, and no regulations on tourist traffic, from a common property perspective is an open access resource (Ostrom 1990). The outcome of such a condition is termed by philosophers, political scientists and economists as ‘The Tragedy of the Commons’ (Gordon 1954; Hardin 1968; Ostrom 1990). Managing common resources to avoid tragedies is influenced by power and resource sharing, representation and equity, partnerships and collaborations across institutional scales and within institutional levels of the managing system (Plummer et al. 2006; Tao & Wall 2009). Understanding these influences is vital to successful co-management of common property resources (Ostrom 1990).

Proponents of adaptive management and the co-management of resources (Ostrom 1990; Berkes & Folke 1998) consider that nature conservation projects should recognize the influence of conservation behavior, and encourage direct links of dependency with the resource being managed or conserved. Developing a direct linkage between livelihoods and conservation or natural resource management is generally less threatening to local communities than strategies that exclude people from their natural surroundings. The concept recognizes and respects cultural and economic ties that people hold with their surroundings, and is thus a positive reinforcement that helps the local communities to deal with or bring about social change.

There are currently three dolphin watching areas in India. The watching of Ganges River dolphins in the River Ganges, (Vikramshila Gangetic River Dolphin Sanctuary) (Hoyt 2005); Indo Pacific humpback dolphins along the coast of Goa in western India (Parsons 1998) and the Irrawaddy dolphin watching industry in Chilika. The former two are opportunistic activities exploited by local fishers living in the region, whereas the Irrawaddy dolphin watching industry in Chilika is the only *organized* dolphin watching industry in India, formed and managed by the local community.

The Chilika dolphin watching industry started in Satpada. As explained in Chapter 2, the industry started with two tourist boats taking interested visitors to see dolphins in 1989 and in 1991 when the Dolphin Motor Boat Association-Satpada was formed. The number of boats increased to 12 boats in 1995, 39 boats in 1997, 112 in 2000 and 180 in 2003. In 2003, the Baba Chaubar Dev Motor Boat Association-Sipakuda was formed as an offshoot of the Dolphin Motor Boat Association-Satpada because of internal disagreements. Both associations are operated by people living in the vicinity of the Outer Channel. In 2006, the Dolphin Motor Boat Association had approximately 244 boats (personal communication President of Dolphin Motor Boat Association-Satpada 2004) involved in tourist activities, primarily in the Outer Channel of Chilika Lagoon (Figure 2.2, Chapter 2). The Orissa Tourism Development Corporation also operates a hotel and runs three dolphin-watching boats in the Outer Channel of Chilika.

Chilika is also traditionally famous for the Ma Kalijai Temple in the central sector (Chapter 2) of the Lagoon. Tourism facilitated by two government tourism agencies and one locally-run association in the South and Central Sectors, mainly caters to cultural and religious tourists from nearby villages. The South and Central Sectors cater to tourists visiting the Nalabana Bird Sanctuary during the months of November to January. All tourist associations offer a range of trips to: 1) see Irrawaddy dolphins, 2) visit the Kali Jai Temple, 3) visit the Nalabana Bird Sanctuary, and 4) visit the beach at the lagoon's sea mouth.

The population of Irrawaddy dolphins in Chilika is ≤140 animals (Chapter 6) and the two highest sources of anthropogenic mortality are believed to be fishing gear and boat propellers (Chapter 3). In 2005, the Chilika Development Authority in conjunction with the Orissa Wildlife Department made it mandatory for tourist boats to have a boat license so that their activities could be monitored and documented (Pattnaik et al. 2007). The Chilika Development Authority also carried out workshops to train boat drivers to use dolphin-watching guidelines and to explore the use of propeller guards (Pattnaik et al. 2007) (Figure10.1). A special section of the Chilika Information Centre for tourists in Satpada has been dedicated to Irrawaddy dolphin biology. Public education material has been developed in collaboration with the Centre for Environment Education, Ahmedabad.

Figure 10.1. Propeller guards designed to be used on boats while dolphin-watching.

In this Chapter, I make a preliminary assessment of the structure and functioning of the dolphin-based tourism industry in Chilika as a community-introduced alternate livelihood. I show the importance of this ecosystem service, based on perceptions of the local community involved in tourism and tourists. I present the viewpoint of tourist boat operators, all of whom are active fishers, towards conservation of dolphins and natural resources. I explore the solutions proposed by them as opportunities for co-management, and discuss the strengths and limitations of community-introduced tourism as a mechanism to conserve Irrawaddy dolphins in Chilika.

10.2. Methods

10.2.1. Study Area

Chilika Lagoon is a brackish water lagoon/lake located in Orissa, India (19° 28'N - 19° 54'N and 85° 05'E – 85° 38'E; Chapter 2, Figure 2.2). A subsistence economy predominates with more than 30% of the adjacent fishing villages actively involved and dependent on fishing or aquaculture or fishery related business ventures (described in detail in Chapters 2 and 4).

10.2.2. Data Collection

I focused this aspect of my study in the Outer Channel region of the lagoon where most dolphin-based tourism occurs. To assess the importance of dolphins and tourism in this region of Chilika, I collected data from two groups of stakeholders: tourist operators and tourists. I interviewed the managers of both locally-run dolphin associations to understand how they work. I carried out a content analysis of one dolphin association by analyzing log book data, and interviewed tourists to better understand the value of the industry. Finally, I carried out questionnaire surveys with fishers involved in tourism to document their perceptions towards tourism and dolphin conservation. I also visited tour operators in Puri city, the closest tourism hub (60 km away) to obtain information on the importance of Chilika in the tourism market.

10.2.2.1. Interviews with Tourist Association Managers and Log Book Analysis

I visited the two motor boat associations which manage tourist boats for villages in the Outer Channel region of Chilika in November 2004, and discussed the objectives of my work with the members. I used open-ended interviews to discuss the structure and functioning of the associations. I obtained lists of the members from each association to document the number of people involved in tourism, and requested a copy of the associations’ outreach materials and charge sheet.

Both associations keep a daily log book of all boat trips and they record the following details daily: 1) boat number which takes a trip with tourists, 2) the kind of trip: a) dolphin watching only; b) sea mouth and dolphin watching; or c) Nalabana Bird Sanctuary, 3) income generated from each trip and 4) start/end time for each trip,. I analyzed the log books of the Dolphin Motor Boat Association-Satpada as this is the first community-run tourist association in Chilika and currently runs 244 boats. I carried out a descriptive analysis of the number and type of boat trips that took place per day from the tourism association over a period of two years from January 2004 to November 2005. I explored the data for annual patterns in tourism activity. I calculated the distribution of income from boat trips across the different stakeholders involved – boat owner, boat association and boat driver-helper to demonstrate how tourism is providing an alternative livelihood for people in the Outer Channel.

10.2.2.2. Interview Surveys of Tourists

To understand the kind of tourists (Indian or Foreign) visiting Chilika lagoon, the value they attach to the experience and the expenses they are ready to commit, I carried out seven pilot interviews on January 17th 2005 in Satpada and used this experience to redesign the interviews for a later date. I chose Satpada for logistical reasons and because it is the first community-run tourist association in Chilika.

I approached tourists, informed them of my PhD project and asked if they would be interested in answering a few questions regarding their tourism experience in Chilika. All tourists I approached were ready to be part of the survey if the interview was short, preferably less than five minutes. Interview surveys followed the James Cook University (JCU) guidelines for interviewing Indigenous Peoples. Human ethics approval, was obtained from JCU under approval reference A940. As a condition of the ethics approval, I obtained verbal consent before initiating an interview and recording it on a tape recorder. A completed interview was regarded as successful. Interview transcripts have been stored as per ethic guidelines.

The interviews followed a loose structure with open-ended questions giving the participant freedom to explain their answers in detail. I asked four main questions: 1) Where the participant lived, 2) how he/she felt about the dolphin watching experience, 3) the cost of the visit to Chilika, including travel, and, 4) if there were any changes the participant would want seen to make the experience better. If participants wished to speak in detail regarding any particular questions, I did not interrupt and kept recording this information. The interviews were transcribed for a subjective analysis.

10.2.2.3. Questionnaires for Tourism Operators

Questionnaires are a constructive tool for collecting information from a target audience regarding ecological and environmental perceptions (White et al. 2005). They are often used to incorporate ecological studies with social and economic data. I used a closed format questionnaire (Table 10.1) with eight questions, where answers were either Binomial (Yes/No) or Rated. Questionnaire surveys followed the James Cook University (JCU) guidelines for interviewing Indigenous Peoples. Human ethics approval was obtained from JCU under approval reference A940. As a condition of the ethics approval, I obtained consent before initiating a questionnaire session and a completed questionnaire was regarded as successful. Questionnaires have been stored as per the ethics guidelines.

Development and Implementation

I designed a questionnaire based on the results from Chapter 2 and 4. I pre-tested the questionnaires with my counterparts in Balbhadrapura village and changed the wording of questions to make them more understandable as required. I then visited households from two villages involved in tourism in the Outer Channel-Balbhadrapura (Satpada Motor Boat Association) and Sipakuda (Sipakuda Motor Boat Association). I chose these two villages as they are the centre of tourism activity, where the association office is located and where tourist boats departed. Balbhadrapura has 249 households (total males: 635, total females: 666; Anon. 2006) while Sipakuda has 87 households (total males: 228, total females: 227;Anon. 2006), with an average of five people per household. I visited every other (alternate) house from the first house visited to administer a questionnaire in Balbhadrapura village. In Sipakuda, I interviewed boat operators and owners at the association office or at the boat jetty from where boats departed. I approached participants, explained my objective for the survey and asked if participants (adults involved in tourism) were interested in being part of the survey. I went through each question with the participant to ensure that it was not misinterpreted.

Respondents were given the option of not providing their personal details. This option was appreciated as it allowed respondents to maintain their privacy. I started the questionnaire by asking participants about the importance of dolphins to them and the reasons for their opinion. I then asked questions regarding their perceptions and knowledge regarding dolphin conservation. The question regarding perceived source of stress to dolphins required the participant to rate the given reasons from one to five where one stands for the most likely cause and five stands for the least likely cause. Respondents were also asked to rate their perceptions of the cause of mortality from four probable sources. Finally, if in the previous question, fishing nets were identified as a source of mortality, I asked them to rate eight different kind of fishing gear using a similar Likkert scale for all questions. To explore if there were fishing methods/gear that participants considered detrimental to the future of fisheries in Chilika, I asked them to mark the list of net as ‘Yes, No or Do not know’.

The last question requested the participant to rate a number of possible mitigation measures to reduce stress and mortality in dolphins and thus help conserve the population. Seven options were provided, and participants were requested to rate them from one (most

Table 10.1. Questionnaire used to collect information on the perceptions of local fishers regarding dolphins and dolphin conservation

QUESTIONNAIRES DATE: VILLAGE: NAME/AGE- (OPTIONAL)

1. How important are dolphins to you?
(a) Very important (b) Important (c) Not very important (d) Not important (e) Neutral

2. Why are dolphins important to you? YES/NO

a) Dolphins are a blessing from God	
b) Dolphins are a source of income	
c) Dolphins help in catching fish	
d) They are beautiful and have aesthetic value	

3. Which of the following according to you can cause stress to dolphins -rate from 1 being primary cause, to 5 being least possible cause?

a) Noise from mechanized boat engines	
b) Movement of mechanized boats disturbing water	
c) Fixed Nets	
d) Gill Nets	
e) Boat traffic	

4. Which of the following according to you can cause death in dolphins-rate from 1 being primary cause to 5 being least possible cause?

a) Accidents with boats	
b) Entanglements in Fishing nets-gill nets of different types or gears	
c) Natural causes –disease	
d) Lack of space and obstruction of free habitat	
e) Other reasons – Starvation	

5. Which of the following nets or gears according to you can cause death in dolphins-rate from 1 being primary cause to 9 being least possible cause?

a) Dubi jaal (Tremmel Nets)	
b) Sahala Jaal (Gill Net)	
c) Bekata Jaal (Gill Net)	
d) Alami Jaal (Shore Seine)	
e) Munni Jaal (Bag Net)	
f) Sankhocha Jaal (Shark net-large mesh size gill net)	
g) Khonda/Puda Jaal (Fixed fish and shrimp box traps with leading segments)	
h) Kokda (Crab trap-baskets on a line)	
i) Hook Lines	

6. Which of these regions according to you harbour dolphins in Chilika?

a) Nalabana-Kalijai	
b) Kalijai-Pathara	
c) Pathara-Rambha	
d) Balugaon to Magarmukh	
e) Jetty to Magarmukh	
f) Jetty to Janikuda	
g) Mahisa-Chaubar temple	
h) Sipakuda-Arakhuda	
i) Close to Sea mouth	

7. Do the following nets or gears pose a threat to shrimp or fish stocks in Chilika? Yes or No

a) Gheri (Aquaculture enclosures)	
b) Alimi (Shore Seine)	
c) Khonda (Fixed fish and shrimp box traps with leading segments)	
d) Zero (Fine mesh size Nets to collect shrimp and fish roe)	
e) Munni (Bag Net)	
f) Sankhocha Jaal (Shark net-large mesh size gill net)	

8. Is tourism good for the local communities in Chilika? Yes or No

9. What are the most important mitigatory measures that can be taken to help conserve dolphins and sustain dolphin tourism in Chilika? Rate from 1 is most effective to 6 being least effective to conserve dolphins.

a) Use dolphin watching guidelines	
b) Use propeller guards	
c) Change the kind of engine used	
d) Reduce noise that boat produces	
e) Stop destructive practices in dolphin rich regions	
f) Manage boat traffic	

effective) to seven (least effective). Most participants became deeply involved in the questionnaire. They often asked if they were correct in understanding a question and would answer with keen interest. (Table 10.1).

10.3. Results

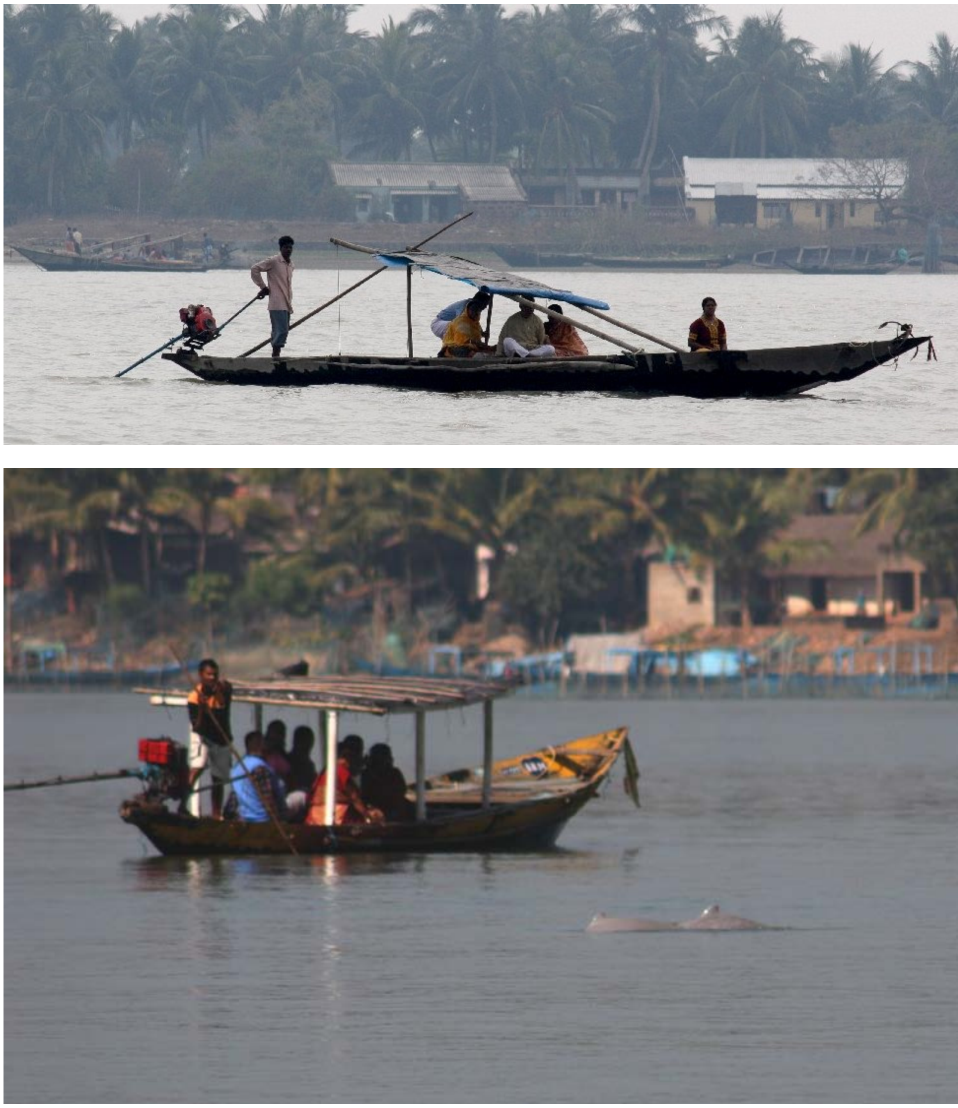
10.3.1. Structure and Growth of Tourism

Twelve villages in the Outer Channel region practice tourism under the aegis of the two dolphin watching associations (Table 10.2) led by a President, Secretary and a Treasurer, elected by members. Fortnightly meetings of all the members are held to maintain and manage operations (personal communication President of Boat Association 2004). Approximately 317 motorized boat owners operate 348 boats (230 boat owners with a total of 244 boats in Satpada and 87 boat owners with a total of 104 boats in Sipakuda) in the Outer Channel. The rift and competition between the two associations was palpable from the discussions with individual members and managers.

Table 10.2. Details of the two community based tourist associations in the Outer Channel of Chilika and the villages that benefit from the tourist activities. The distinction between fishers and non-fishers is explained in Chapter 2.

Motor Boat Association	Villages involved	Number of association members/ households per village	Fishing/Non-Fishing village
Dolphin Motor Boat Association -Satpada	Balbhadrapura	78/249	Fishing
	Gadh	19/50	Non-fishing
	Bankijal	9/45	Non-fishing
	Alupatna	119/294	Fishing
	Nuavadi-bhusai	5/30	Fishing
	Balpatna	?	
Ba Chaubar Dolphin Motor Boat Association-Sipakuda	Pirijipur	4/96	Non-fishing
	Sipakuda	35/87	Fishing
	Gangadharpur	10/80	Fishing
	Golapur	3/31	Non-fishing
	Guptapur	1/25	Non-fishing
	Banmalipurpatna	35/51	Fishing

Fishers who owned boats with motorized engines joined the dolphin-watching associations for part time tourism activities and employed young adults from their village to drive the boat. The only additional infrastructure required to convert a fishing boat to a tourist operation was adding a tarpaulin rooftop to the boat to provide shade to tourists and to be recognized as a tourist operating boat (Figure 10.2).



A)

B)

Figure 10.2. (A) Fishing boats converted to dolphin-watching boats in Chilika Lagoon India, (B) with a boat driver showing Irrawaddy dolphins to tourists

The association offered seven kind of trips, six of which include dolphin watching. The charge for a trip was set at standard rates/per trip that ranged from 400 INR (8.30US$) for a two hour dolphin watching trip, to 1500INR (31.00US$) for a day trip of nine hours to see dolphins, beach and migratory birds in Nalabana Sanctuary. A boat was allowed to take one family of six plus two children. The option of sharing a trip with other tourists was not permitted.

The months of October to January are peak periods for tourism activity, with greater than 2000 boat trips per month for the Dolphin Motor Boat Association-Satpada (Figure 10.3). The log book entries suggested that tourists most often chose a three hour trip which included dolphin watching and visiting the sea mouth to rest on the beach (Figure 10.4). The association issued boat numbers, and boats went out in serial order which provided an equal chance to all boat owners to take tourists out on a trip. The boat traffic for tourists seemed continuous with a short break at lunch time (1pm-3pm). The number of boats around a group of dolphins varied from one to at least seven boats at any given time (personal observation). Boat owners employed drivers and helpers usually from their own village. The average income from a single boat trip was divided as follows (all figures averaged over 2004-2005, see Table 10.3): the boat owner received 80% (a minimum of 300INR/2 hours of boat trip), the boat driver received 9% (a minimum of 50INR/2 hours of boat trip) and the boat association received 11% (a minimum of 50INR/2 hours of boat trip) of the money charged per trip (Table 10.3). Income was also generated for villagers via the growth of traditional eateries and small stalls selling packaged snacks and cold drinks. Involvement in the industry generated self esteem as exemplified by the following comment from an interview with an elder running a shop,

"Daughter, I have fished here in Chilika for more than 50 years now, and fishing will always be primary, but I feel I get more respect and recognition from interacting with tourists. I like this, nobody respects us as fishers"

Table 10.3. Distribution of tourist income in percentage and Indian Rupees per trip, amongst boat owner, boat Association and boat driver (1US$=48INR)

Year	Boat owner	Boat Association	Boat driver
Jan 2004-Nov 2004	83% ; 330INR/trip	10% ; 40INR/trip	7% ; 30INR/trip
Jan 2005-Nov 2005	75% ; 300INR/trip	12.5% ; 50INR/trip	12.5% ; 50INR/trip

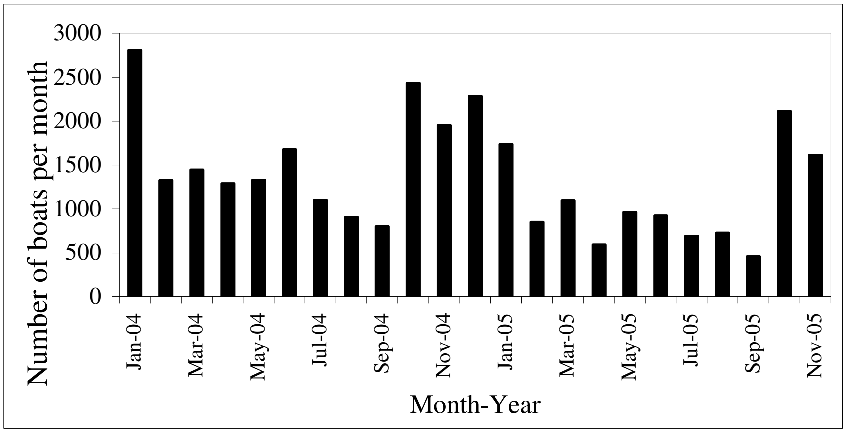


Figure 10.3. Number of boat trips per month from the Dolphin Motor Boat Association-Satpada in the Outer Channel in Chilika, India in 2004-2005 based on log book data maintained by the Dolphin Motor Boat Association-Satpada**.** This graph does not include data from the Ba Chaubar Dolphin Motor Boat Association, Sipakuda.

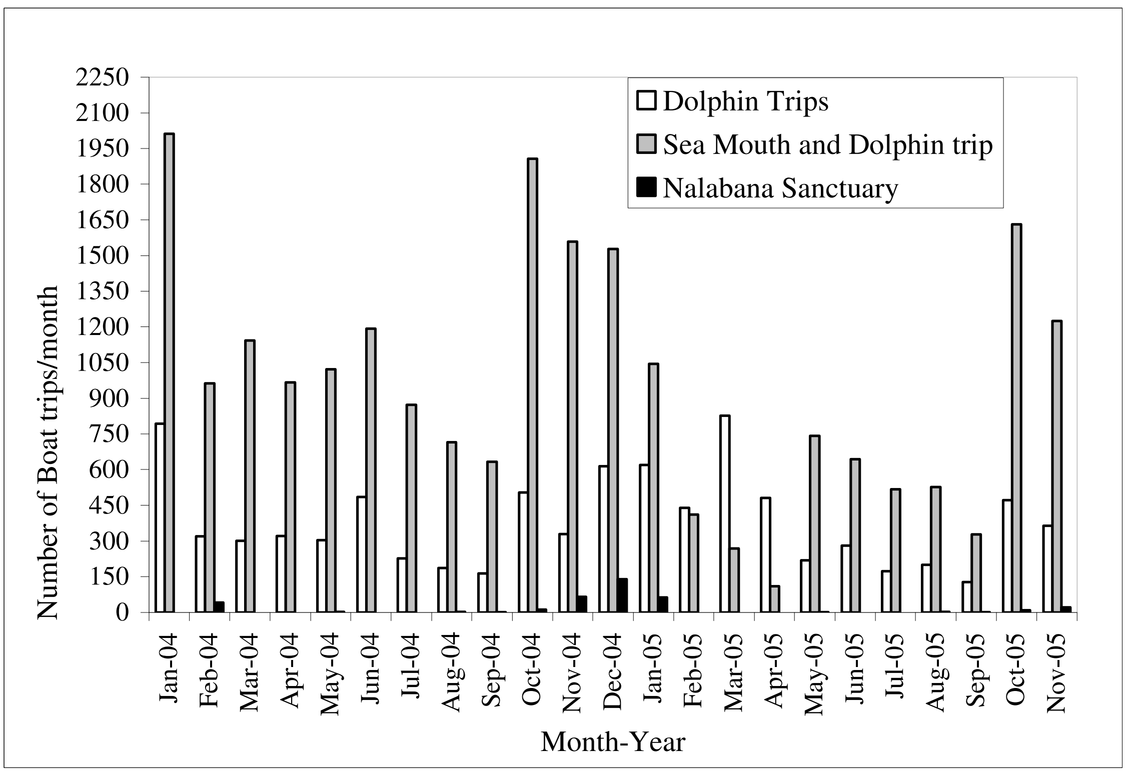


Figure 10.4. Different types of boat trips taken by tourists per month in 2004-2005 in the Outer Channel in Chilika, India based on log book data maintained by the Dolphin Motor Boat Association-Satpada, Chilika Lagoon. This graph does not include data from the Ba Chaubar Dolphin Motor Boat Association, Sipakuda.

10.3.2 Preliminary Interviews with Tourists

I interviewed a very small sample of just 14 tourist groups on November 20th 2005 at Satpada using semi-structured interviews. Groups generally consisted of a minimum of two people and a maximum of eight people. Other than one couple from France and one tourist from U.S.A, all tourists were Indian nationals who had arrived in tourist buses or private taxis from local destinations like Puri (60km away) or Bhubhaneswar (120km away). Three groups (one each from Karnataka, Jharkhand and Himachal Pradesh) were visiting Chilika as a side tour from Puri city. Six groups were visiting from Bhubhaneswar and four groups from Calcutta. Nine of the 14 tourist groups had come to Chilika especially to see the dolphins, while the rest had been informed of the dolphin's presence by their travel agent after arriving in Orissa. On average a group paid 1500INR (31.00US$) for its boat trip irrespective of the number of tourists in the group.

When asked about their dolphin watching experience in Chilika, two out of the 14 groups interviewed said that the experience was not worth the money they had spent. Two groups said that it was an average experience, because they could hardly see the animals, but the rest said that the experience was wonderful. All the participants said that boat drivers had put off their boat engines when close to or around dolphins. Examples of answers from respondents are provided below to illustrate the range of tourist experiences:

"We saw dolphins for almost 30 minutes and the man driving the boat was genuinely interested in the dolphins. He put the engine off every time we saw the dolphins, but the other tourists in other boats were making a lot of noise. Overall, it was a lovely experience"

"We saw dolphins for almost 15 minutes and the boat driver put off the engine when we were close to the dolphins, it was an okay experience"

"We did not get a chance to see dolphins clearly, but it was a great experience coming here"

When asked about what changes they would like to see to make their experience a memorable one, all people reported that the facilities available to tourists were not good enough for the price paid. The most common complaint was the lack of toilet facilities and of availability of good quality food on the boat or at the beach where all boats stop for a break. One group from USA was happy with the total experience and did not want anything else changed,

"No…do not want to change anything The best part of it and the value of it for tourism is to experience it the way it is and not some artificial addition to it..like more comfortable boats and things like that. If you want to experience it, it should be the original environment"

The group from France suggested making binoculars available on hire basis and said that *"It was magic the way it is, do not change anything"*

Another group suggested that boats should have a guide aboard to help in dolphin and bird sighting, and who tourists can communicate with. They considered that a guide would make the trip more professional and worth the money. Some of the groups from India suggested that the charge per trip was slightly expensive for them, especially since they could not share the cost with any other groups. A group of dancers from Karnataka, India said that

"We found the boat trip to be slightly expensive, but if the boat was more comfortable and there were facilities like toilets and food at the beach, then we would have been satisfied. Anyways, we are happy that the local people here benefit from tourism so it is okay."

An elderly couple from India said,

"We are happy with the place, but feel it can be expensive for small families or couples and that there should be a facility to share boats with other people. Also while the locally run tourism is good for the community and the government, earnings should not be at the cost of unbalancing ecology. The idea is to maintain tourist attraction provided the ecological balance is maintained"

I had opportunistic discussions with travel agents and tour bus managers in Puri and found that there was large scale publicity and marketing of 'dolphin watching in Chilika'. All the travel and tour agencies marketed day trips to Chilika. Discussions with the travel agents suggested that aggressive marketing had been developed in conjunction with the local motor boat associations in Satpada and Sipakuda, who are competing by providing incentives like food and monetary benefit to taxi drivers and tour agencies. The cost of this transaction varied from 100INR to 300INR/per trip[6] to Chilika (approximately 6% of total cost of a trip).

10.3.3. Questionnaires with Fishers involved in Tourism

Forty-one questionnaires were completed by fishers from two villages involved in dolphin tourism. All participants were both fishers and tourist operators. All individuals I approached, other than one in Balbhadrapura, were willing to complete the questionnaire. Twenty-nine questionnaires (11% of households) were completed by residents of Satpada and 22 (13% of households) questionnaires by residents of Sipakuda.

10.3.3.1. Perceived Importance of Irrawaddy Dolphins in Chilika Lagoon

All 41 participants considered dolphins to be very important: 31% said dolphins were important to them as a sign of fish presence that helped fishers decide where to place their nets and chased fish into the nets; 24% said dolphins were an important source of income from tourism; 23% stated that dolphins were important in maintaining proper functioning of the Chilika ecosystem, and 13% stated that dolphins were a Blessing from God (Figure 10.5). All participants wanted tourism to continue in the region as a source of income.

[6] The exchange rate during my study period ranged from 1US$=43INR to 45INR based on data from www.xe.com/ucc/

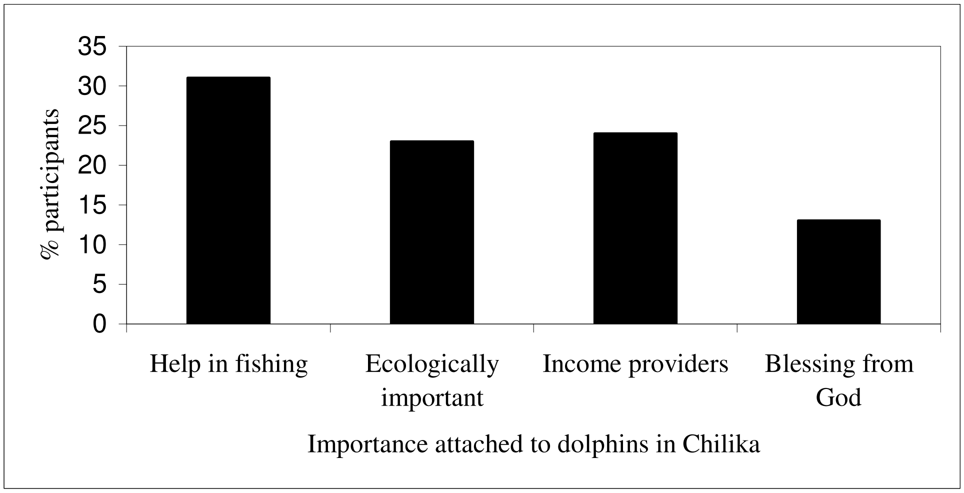


Figure 10.5. The importance attached to Irrawaddy dolphins in Chilika identified by local fishers, who are also actively involved in tourism from questionnaire surveys (n=41).

10.3.3.2. Perceived Sources of Disturbance in Chilika Lagoon

Respondents considered that the top two sources of stress to dolphins were boat propeller activity (46%), noise caused by motorized engines (41%), followed by the presence of gill nets (30%) and fixed fishing nets (20%). Boat traffic *per se*, was rated as the least likely source of disturbance (17%), inconsistent with the top two perceived causes of stress (Table 10.4).

Table 10.4. The top four, rated causes of stress to dolphins in Chilika identified by local fishers from questionnaire surveys (n=41)

Top two causes of stress to dolphins as identified by respondents	**% of respondents**
Propeller activity (physical activity in the water)	46
Engine noise	41
Gill nets	30
Fixed nets	20
Boat traffic	17

10.3.3.3. Perceived Sources of Mortality

The top two sources of dolphin mortality were considered to be lack of space for dolphins (63%) and natural death (61%), followed by death from net entanglement (43%) and boat accidents (27%) (Figure 10.6, Table 10.5). Alimi (shore seine) and sankhocha nets (shark net) were perceived as the top two causes of fishing-related mortality, followed by kaata (hook line) fishery (Table 10.7, Figure 10.5). I found 92% of participants considered gheri (aquaculture enclosures) detrimental, 65% found zero nets (fine mesh size) detrimental, and 55% considered Alimi nets (shore seine nets) detrimental for fisheries. Thus the nets considered detrimental to fisheries were somewhat different from those thought to cause mortality in dolphins; only Alimi nets (shore seine nets) were considered detrimental to both dolphins and fisheries.

Table 10.5. Top two rated causes of mortality to dolphins in Chilika identified by local fishers from questionnaire surveys (n=41)

Top two perceived causes of mortality	% of participants
Net Entanglement	44
Lack of space	61
Starvation or natural death	63
Accidents with boats	27

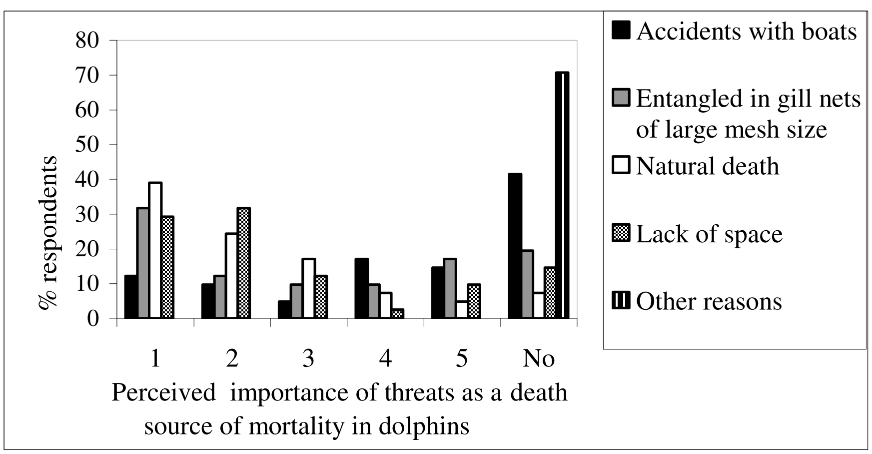


Figure 10.6. The perceived cause of death of Irrawaddy dolphins in Chilika lagoon, rated from 1 to 5, where 1 stands for the most common cause of death and 5 stands for the most unlikely cause of death in dolphins. The data are from 41 fishers who responded to the questionnaire survey. Some of the fishers did not identify any situation to be a cause of death.

Table 10.6. Fishing gear ranked in the top two types of nets that can cause dolphin mortality in Chilika lagoon as identified by fishers who are also involved in tourism, based on a questionnaire survey (n=41)

Fishing gear identified by local fishers as top two causes of dolphin mortality	% of respondents
Alimi (Shore seine)	48
Sankocha (Shark net)(multifilament large mesh size gill net)	32
Katta (Hook line)	26
Dubbi (Tremmel net)(small mesh size gill nets)	19
Munni (Purse seine)	17
Bekta and Saal (medium mesh size gill nets)	15
Khonda (Fixed net traps on stilts)	11
Kokda (Crab traps)	1

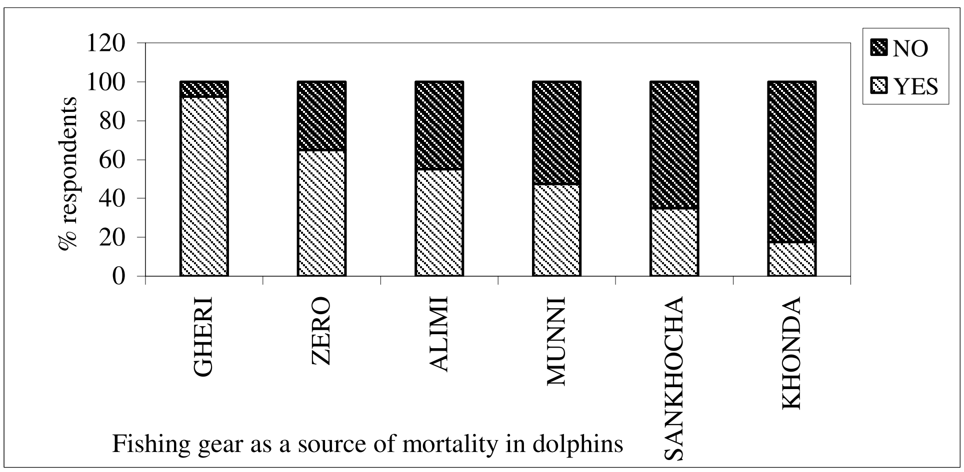


Figure 10.7. The relative importance of different types of fishing gear as a source of mortality for Irrawaddy dolphins of Chilika Lagoon. These nets were identified by local respondents (n=41) in a questionnaire survey in Chilika lagoon. See Table 6 for English names of gears and Appendix D for available pictures of different fishing gears.

10.3.3.4 Suggested Solutions and Mitigatory Measures

The top two solutions (Table 10.7) suggested by participants to reduce threats to dolphins were: a) to remove all obstructions such as fixed fishing gear and gill nets from the channels used by dolphins during normal movements (51%), and b) to follow the dolphin watching guidelines provided by the Chilika Development Authority (34%) . Thirty percent of respondents suggested a ban of detrimental fishing techniques like shark nets and shore seine nets; 27% stated that boat traffic needed to be managed; 19% percent believed that the use of propeller guards would greatly reduce mortality and disturbance to dolphins; while 19% suggested using noise absorbers to reduce disturbance from engine noise; and 17% thought the use of more sophisticated inboard Yamaha engines instead of long tailed outboard engines would be useful.

Table 10.7. Mitigatory measures ranked in the top two solutions offered by local fishers to reduce mortality and conserve dolphins in Chilika lagoon, from questionnaire surveys (n=41).

Solutions (ranked in the top two mitigatory measures)	% of respondents
Avoid obstructing dolphin movement	51
Follow dolphin watching guidelines	34
Manage detrimental fishing techniques	31
Manage boat traffic	26
Reduce boat noise	19
Change boat type	19
Use propeller guards	17

10.4. Discussion

Irrawaddy dolphin watching tourism is now an established occupation in the Outer Channel of Chilika. The focal area is less than 35km^2, the chance of sighting a dolphin during a day trip to the Outer Channel is close to 100%. Community-run tourist operations with a total of approximately 331 boats generate income for a range of stakeholders in the region, and fishers can easily switch between active fishing and tourism activities. The industry also provides income to people who do not own boats and has led to the development of a government museum, eateries and roadside shops. The eateries, shops and phone booths operated by local communities for tourists provide income possibilities for people living in the villages.

The importance of dolphins as a sign of fish presence and a source of income shows that dolphins offer benefits to people involved in both fishing and tourism. Only 13% of respondents regarded dolphins as a ‘Blessing from God’, while most participants attributed their importance to the more tangible economic benefits from fishing and tourism. This result was also evident in Chapter 4, where positive affiliation towards dolphins was not affected by age, but by region. The myths regarding the dolphin as a 'Blessing of God', are passed down though the generations, though not widely believed, but the more pragmatic importance of using dolphins for locating fish and obtaining income from tourism are widespread and tangible.

The data show that local communities are aware of the risks faced by dolphins, and could distinguish factors that cause disturbance and mortality. Underwater propeller activity and engine noise were perceived as the major sources of stress, and habitat fragmentation, obstruction of movement and habitat unsuitability were seen as a major source of dolphin mortality by the participants. All interviews with my small sample of tourists suggested that boat drivers put their engines off in the presence of dolphins. This preliminary result suggests that boat drivers have gradually become aware of the physical risks faced by the dolphins and also of the potential for boating activity to chase them away to other areas. In-depth studies of the interactions between tourist vessels and dolphins and more comprehensive surveys of tourists are required to test these conclusions.

Results from Chapter 4 and Chapter 7, suggest that changes in the available habitat size and quality have had a negative effect both on the well-being of people living in the vicinity of Chilika Lagoon, and the distribution of dolphins in the Lagoon. Habitat fragmentation is thus a primary source of concern for Chilika, for both social and ecological reasons. Removal of obstructions to dolphin movements was perceived as the most effective conservation strategy by participants. The actions would increase the amount of space available to dolphins and ease their movement between the Outer Channel and South Central Sectors. This strategy would also increase the free movement of roe and fish into the Lagoon. Currently both roe and fish are caught in nets obstructing channels. Most participants did not rate fishing nets to be a very high cause of dolphin mortality, but they identified shark nets (large mesh size gill-nets), shore seine nets and hook lines as sources of mortality.

The management and regulation of the fisheries in dolphin-rich areas of the lagoon is suggested by participants as an opportunity to greatly reduce dolphin mortality. Given the life history of slow-reproducing marine mammals, I estimated that anthropogenic adult mortality of greater than one Irrawaddy dolphin per annum will cause the population to decline (Chapter 9). Sources of unnatural mortality thus have to be controlled as the highest priority if the population is to be conserved. The awareness amongst the local community and suggested solutions to reduce disturbance and mortality should be used as a platform to discuss this issue. The solutions offered by local stakeholders in Chilika can fill the gap between resource users and conservation practitioners if both groups find a mutually agreeable solution.

Tourists from surrounding regions visit Chilika all through the year. Most of the 14 tourist groups surveyed suggested that they would return or recommend the place to others suggesting the future tourism potential of Chilika. Ten out of 14 tourist groups were happy with their dolphin watching experience, but also found the charge for the boat trip to be slightly expensive.

During the months of October to January, 2000 boat trips/day were recorded in an area of less that $30km^2$. Dolphin-watching boats functioned all day but the majority of boats went out between 9am and 1pm with number of trips in the afternoon less than in the morning. The number of tourists arriving to see dolphins (50,000 to 100,000 per year as calculated from number of boats* minimum two and maximum six passengers) is large. Tourist operators were interested in following dolphin watching guidelines, but not prepared to reduce or manage boat traffic. The differences between these two reasons suggests that terms such as ‘boat traffic’ could be considered threatening if they are framed in a negative context.

There are currently no limits on access to dolphins and the amount of time each tourist vessel can spend with dolphins makes the dolphin watching an open-access common property dilemma. All the stakeholders benefiting from the dolphin watching industry will lose if impacts on dolphin health and behavior are not considered within the management of the industry. Dolphin watching guidelines in many developed countries allow only three motorized boats/vessels around a group of dolphins at any one time, at a distance of at least

100m from the group (Constantine 1999). No such limitations exist in Chilika, with the dolphin groups in the Outer Channel of Chilika being disturbed for at least six hours/day. The issue of managing the number of boat trips per hour will be acceptable and seen positively only if the income generated is not reduced dramatically. It would be preferable to increase the standard rates of the dolphin watching trip so that the gap between boat owner and driver could decrease, but this is seen as a problematic step as most national tourists found the entire trip to be slightly expensive.

My discussions with both dolphin watching associations (personal communication with managers of Associations) suggest that managing boat traffic in dolphin rich regions of Chilika will be a challenge. Based on the absence of a set of guidelines or an official Code of Conduct around dolphins, or a limit on the number of boats allowed around dolphins, the harassment to dolphins in the Outer Channel of Chilika is much higher that would be permitted in developed countries. The rift and competition between the two associations leads to aggressive marketing for tourists and taxi drivers in Puri and Bhubhaneswar. The involvement of the government agencies (Orissa Forest Department, Orissa Tourism Development Authority and Chilika Development Authority) in better managing boat traffic and in resolving conflict between the two boat associations by initiating dialogue is likely to have positive long-term effects on dolphin health and survival.

Since the 1980s, the socio-ecological system of Chilika Lagoon has been in a state of social and biophysical flux. The capacity of communities to manage their primary livelihood of fishing is very limited and their capacity to deal with changes in power, management, income and environment is variable. Like the tourism industry, the fishing industry in Chilika, is an example of the ‘Tragedy of the Commons’ where unlimited open-access to the resource currently apparently benefits everyone involved in the short-term, but everyone also shares in the burden of any negative and long term impacts. Locally managed tourism activities may empower communities and buffer them from externalities like falling fish catch. But unless such activities are sustainable, this buffering will be short-term. Mutually agreed controls are required to sustain the tourism and fishing industry in Chilika Lagoon.

In developing countries, species and habitat conservation is a livelihood issue. The conservation success of incentive strategies is limited and not always successful on its own if local perceptions of the resource are different from those of conservation practitioners (Agrawal & Gibson 1999; Martinez-Aliers 2002; Agrawal & Ostrom 2006). The interdependence of different stakeholders in the planning and management of the tourism industry, each contributing knowledge and perspectives on management issues is the basis of tourism within the co-management framework. The local stakeholders are aware about the importance of dolphins, and the risks they face. The prospective solutions offered by them, suggests that conditions are conducive to conservation outcomes of interest in the future. However, changing the management of tourist activities in the Outer Channel of Chilika will be extremely difficult. The relatively unregulated industry, in combination with limited capacity for enforcement of Dolphin Watching Guidelines, poses significant constraints on learning and changing – two fundamental components of the adaptive co-management paradigm (Armitage et al. 2008).

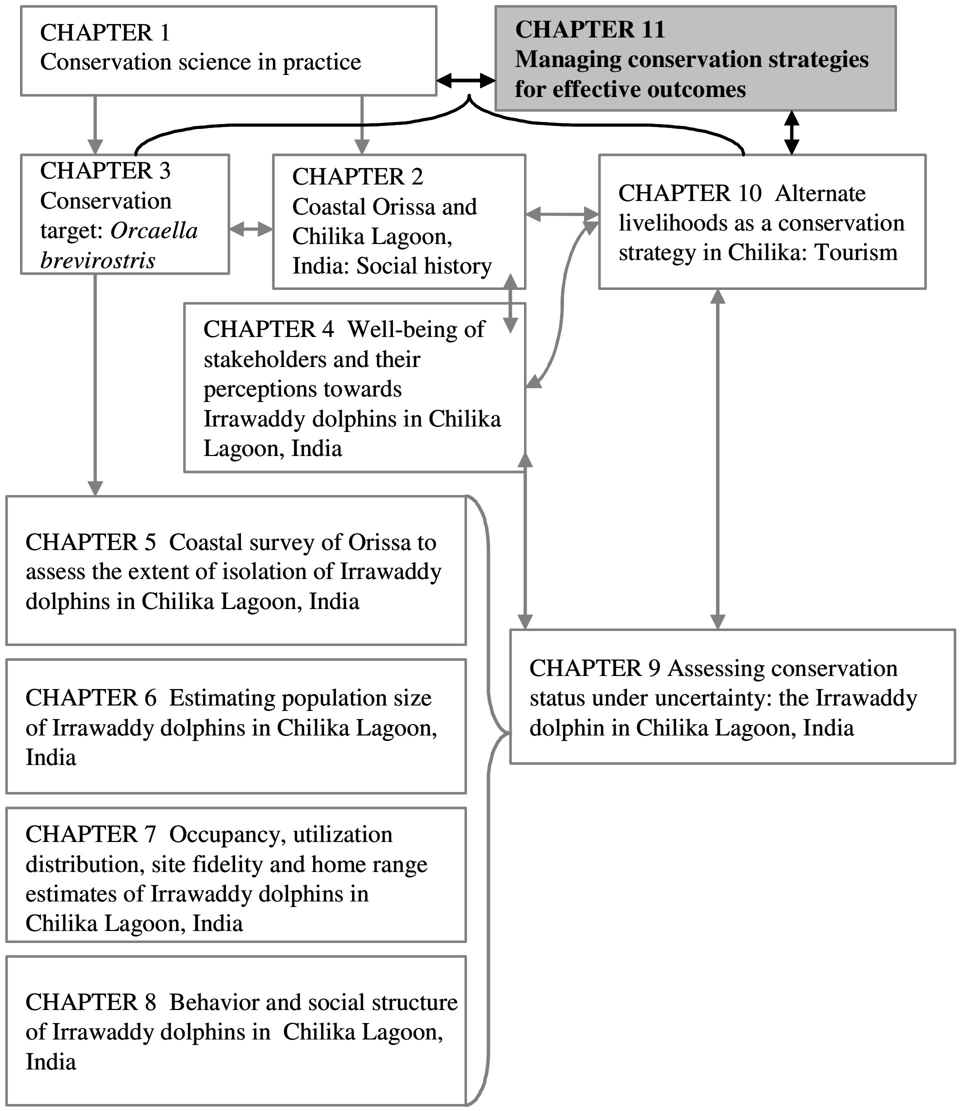
Trust and collaboration between the two tourist associations is a pre-requisite to successful co-management of the tourism industry to conserve dolphins and sustaining livelihoods. Communities need to understand the benefits from conservation outcomes, while conservation practitioners and enforcement agencies need to understand the politics of ecological conservation. Thus the capacity of both the community and the managers of Chilika will need to be increased if the dolphins and dolphin-watching industry are to be conserved.

10.5. Chapter Summary

- Irrawaddy dolphins are economically important to communities in Chilika Lagoon.
- Two locally-run tourism associations currently function in the Outer Channel of Chilika. They run a total of 348 boats in the Outer Channel.
- Interview surveys in conjunction with content analysis and questionnaires helped obtain a holistic view of multiple stakeholder perspectives on the dolphin-watching industry.

- The peak season in Chilika tourism was during the months from October to January with an average of 2000 boat trips per month from just one of the two tourism associations. The industry provided a range of income opportunities to people from 12 villages and more than 600 families.
- Movement of boat propellers and engine noise are seen as major sources of stress to dolphins. Obstruction to dolphin movement and unsuitable habitat are seen as the two main causes of mortality for dolphins. Shore seine nets, shark nets and hook lines are perceived as sources of mortality in dolphins. Managing agencies should consider this information to reduce friction while designing future conservation strategies.
- Removing obstructions for free movement, following dolphin watching guidelines and managing detrimental fishing gear are suggested as the main solutions to reduce mortality of dolphins. The incorporation of these social perceptions into designing dolphin conservation strategies with direct involvement of the local community, could help foster successful conservation actions.
- Future projects need to be urgent, and need to focus on capacity building and the management of the tourism industry at two scales: a) by bringing about collaborative interactions between tourists, fishers, and tour boat operators to limit direct impacts through controlling boat traffic and mitigating disturbance; and b) collaborative interactions among management agencies and local enforcement in a manner that provides a holistic vision for the management of the Chilika socio-ecological system.

11 MANAGING CONSERVATION STRATEGIES FOR EFFECTIVE OUTCOMES



In this concluding chapter, I review my results and the current conservation strategies used for conserving Irrawaddy dolphins in Chilika using a conservation planning framework. I attempt to measure the role of the community-introduced alternate livelihood of tourism as a conservation strategy. I propose future socio-ecological goals and discuss the role of 'communities', multilevel institutions and conservation practitioners in future conservation practice.

11.1. Conservation Planning in Chilika

As explained in Chapter 1, the main aim of my thesis was to inform conservation planning of endangered species in human-dominated regions of developing countries using a case study of Irrawaddy dolphins in Chilika Lagoon, India. In this chapter I review my results within the context of the general conservation planning framework and the objectives of my thesis as discussed in Chapter 1. I review strategies that are in place or have been proposed by the government to conserve Irrawaddy dolphins inn Chilika. I present an operational framework for conservation management in Chilika with dolphins as the focus of the framework.

11.2. Objective 1: To carry out a systematic assessment of Irrawaddy dolphin conservation in Chilika Lagoon, India

Social Landscape where Conservation Operates

A human population of approximately 200,000 depends on Chilika Lagoon for resources. Irrawaddy dolphins face a range of threats from over-fishing to tourism. Carcass analysis suggests that the major threat in Chilika is entanglement in fishing nets (Pattnaik et al. 2007). Life history studies suggest that controlling adult mortality is of the utmost importance to sustaining slow-reproducing mammalian populations, and unnatural adult mortality of one or more dolphins per year (Chapter 6) would decrease the population. The incorporation of sustainable use of resources and dolphin conservation goals into the daily lives of the people of Chilika will require understanding the societal circumstances and preferences of local stakeholder groups, their interrelationships with each other, and with actors at other levels of the system. The ongoing conflict between the two major groups of stakeholders (fishers-non fishers); between the two dolphin-watching associations and the dissatisfaction of stakeholders towards government-imposed policies (Chapter 2) reduce trust and limit conservation initiatives and outcomes.

Isolation and Abundance of Irrawaddy dolphins in Chilika Lagoon

The results of the coastal survey (Chapter 5) indicate that Chilika Lagoon is the critical habitat for Irrawaddy dolphins along the Orissa coastline. The absence of recent Irrawaddy dolphin carcasses or sighting data elsewhere along the coast suggests that the population in Chilika is geographically isolated. I estimated the population size of Irrawaddy dolphins in Chilika is small (109 to112 individuals at CV=0.07 from Closed Models; and 140 at CV=0.25 from Open Models), based on photo-identification surveys from November 2004 to December 2006 (Chapter 6). A power analysis indicated that if the population decreased at 5% per year it would take seven years to detect this decline; even a decline of 20% would take three years to detect using the same survey protocols, by which time a population of 112 animals would have been reduced to 57 animals. The data suggest that conservation actions need to acknowledge the risk that faces the population, and initiate interventions using collaboration with local fishers in the Outer Channel immediately if population declines are to be avoided.

Detecting trends in population size is a standard ecological measure of conservation outcomes at the ecological scale. Monitoring programs need to be affordable, cost-effective and produce robust results. Detecting trends in small populations of marine mammals is very difficult (Taylor et al. 2007b) and assessing survivorship is likely a better performance indicator for measuring the outcome of conservation strategies. Adopting photo-identification based Mark-Recapture analysis as the standard protocol would thus benefit future conservation planning programs in Chilika. This approach would provide robust estimates of population size and most importantly survival rates in its simplest application. Moreover, given that the initial costs of surveying the population to build a photo-catalogue have already been met, and the catalogue will be readily available on the internet, the population can now be monitored relatively easily using a maximum of three surveys per year.

Occupancy, Utilization Distribution, Site fidelity and Home Ranges

I estimated the Extent of Occurrence for Irrawaddy dolphins in Chilika as <330km^2; and the Area of Occupancy as <131km^2. Both these estimates indicate that the dolphins use less than half of the lagoonal area, at least in the dry season. The dolphins occur in two core areas, one in the Outer Channel and one in the South-Central Sector. Analysis of the home ranges of individual Irrawaddy dolphins sighted on more than eight occasions showed that most animals had similar and small home ranges while a few animals ranged more widely. The standard deviation of the distances of each individual from their mean centre varied from 0.33km to 14.33km (Figure 8.2). Over 80% of individuals were always found within 10km of their mean centre. There was a large overlap between individual homes ranges, with 11 individuals exploring the entire study area, while 19 individuals were never observed out of their core areas. The quality and carrying capacity of the core habitats thus appear critical to the survival of dolphins in Chilika. Sustaining habitat quality should thus remain a central conservation strategy for biodiversity and dolphins in Chilika.

Behavior and Social Structure in Irrawaddy dolphins of Chilika Lagoon

The dolphins were found across the entire range of water depths and salinity, and group sizes did not vary significantly with changes in environmental variables. The average group size of Irrawaddy dolphins in Chilika is small (3-4) and an analysis of association indices suggests that the society is fluid. I detected strong associations for only 14 individuals, while weak bonds exist between a further 34 individuals. In some other regions of the world, *Orcaella* live in more structured societies with constant companions. The reason for this variation is uncertain but may be relate to the relationship between population size and the spatial configuration of suitable feeding habitats. The effect of recent habitat changes in Chilika on social structure is impossible to assess but long term studies may provide valuable insights into how anthropogenic impacts affect social structure in dolphins.

Conservation Status of Irrawaddy dolphins in Chilika Lagoon

Based on data from this thesis and peer-reviewed literature, I assessed the Irrawaddy dolphin population in Chilika lagoon as Critically Endangered using both the IUCN Red List criteria and the RAMAS Red List software. Both methods list the population of dolphins based on Criterion A: population size and reduction. Based on Criterion B of the

IUCN Red List which categorizes extinction probability based on habitat availability and quality, the population is Endangered.

Local Perceptions towards Conservation

Most local people from Chilika like to observe dolphins and see them around when they go fishing, and to an extent revere them. Ninety-eight percent of the 400 participants from local villages stated that the fish catch had fallen to less than 70% of former levels in the past 10 to 15 years and that their life was much better 10 to 15 years ago. Of the 400 participants, 56% believed the location of the new sea mouth, the natural closure of the old sea mouth and silting of the Palur channel, were responsible for the fall in fish catch rather than over-fishing. Thirty-four percent of participants thought it was not necessary to conserve dolphins but that it was necessary to sustain fish resources, while 66% said they were keen on conserving both dolphins and fish.

The interview surveys suggested a reduction in distribution of Irrawaddy dolphins in Chilika over the last 15 to 20 years. Ninety-four percent of participants reported a decrease in the number of dolphin encounters. Sixty-two percent of participants identified incidental catch of dolphins in fishing nets as the major cause of dolphin mortality, a conclusion substantiated by carcass analysis.

Residents of different regions in Chilika differed in their perceptions toward dolphins. The residents of the Outer Channel Region showed the highest positive affiliation. In the Southern Sector, younger interviewees (<45 years old) had a lower affiliation towards dolphins, while in the Northern and Central Sectors, interviews with boat owners (motorized or non-motorized) showed higher affiliation towards dolphins than those without boats. This information suggests that experiential and economic factors influence affiliation toward dolphins. This information is very important for designing awareness programs and education material as part of a conservation plan for targeting awareness programs. Using knowledge collected from local stakeholders and key individuals to help in awareness programs will empower local communities and should strengthen the conservation process. This information also helps assess if stakeholder behavior is open to changes associated with mitigating threats to the dolphins.

Results of the systematic assessment clearly suggest that the conservation of Irrawaddy dolphins in Chilika requires the development and urgent implementation of a conservation plan informed by both social and ecological factors.

11.3. Objective 2: To review current strategies to conserve dolphins in Chilika

Role of Institutions in Conservation Planning

The implementation and management of conservation strategies in regions like Chilika are influenced by the complex social system (Berkes 2004) of hierarchical levels (Ostrom 1990; Ostrom et al. 1999), each identified by multiple cultural institutions (e.g., castes of fishers and non-fishers) and political agendas (Figure 11.2). The information from Chapter 2 and the interviews discussed in Chapters 4 and 10 suggest that there is a mismatch in natural resource management scales in Chilika. The ecosystem is officially managed by government agencies on the basis of expert opinion. Stakeholders are not included in decisions. Fishery resources and Irrawaddy dolphins are common property resources (Ostrom 1990) in Chilika. Results from Chapters 2, 4 and 10 suggest that property rights over resources also shape the situation in Chilika, yet few decisions regarding resource use are taken by stakeholders. Instead, resource extraction is controlled by organizational levels above the local level (Figure 11.1), using a top-down approach to policy implementation.

Currently, at the local community level there exists a tragedy of the commons with rival tourism associations and fisher-non fishers competing for limited resources. The local communities are not empowered to make decisions regarding the use of fish resources, and their traditional responsibility of sustaining Chilika has been replaced with a loss of social capital and trust. Collaborative arrangements for sharing fishery resources were traditionally present in Chilika (Sekhar 2004; Sekhar 2007). Interviews with the

Maschajivi Mahasangh (consisting of fisher unions from the South, Central, North and Outer Channel regions) of Chilika suggest that local leaders have requested that the traditional system of fishery management be allowed to function again (Kothari & Pathak 2006) in Chilika but the idea has not received attention from higher levels of the social system.

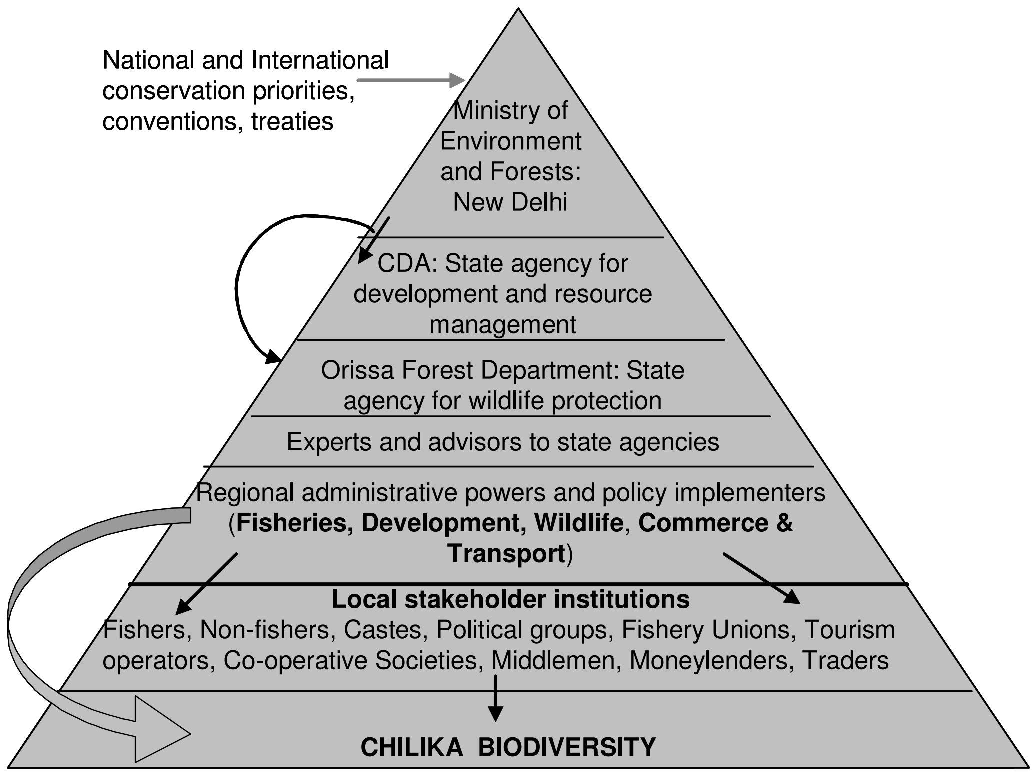


Figure 11.1. The organizational set up of governance and top-down management in Chilika Lagoon, India, with the various scales and levels of human institutions that control or depend on (gray boxes) the biodiversity of Chilika. Arrows are indicative of the magnitude and direction of influence and control.

Political forces, when misused, can reduce collaboration and sharing of power horizontally (between the fishers and non-fishers, and between competing tourist associations) and the acceptance of collaborative space vertically (between enforcement agencies, conservation bodies and local community). As in other parts of India, vote bank politics[7] are rampant in Orissa, and the Chilika constituency is divided on religious and political grounds across at least three major political parties. The political agendas of the higher levels of organization in the social system can exploit local needs and manipulate incentives to foster divisive governance. The result is an increasing loss of trust in governance systems. Rebuilding trust in management systems and links between local communities is the social capital that will be required for co-management to succeed in Chilika (Sekhar 2007) not only for sustainable fisheries but also to conserve dolphins.

Conservation Measures

Several measures have been taken to mitigate the threats to the dolphins in Chilika but the outcome of these measures has not been assessed. Current conservation strategies in Chilika include penalties for violation of the *Wildlife Protection Act (1972) of India* which lists Irrawaddy dolphins as a *Schedule I* species (rare and endangered totally) (Chapter 3). Imprisonment for a mandatory term of not less than three years and up to seven years, and a fine of not less than 10,000 Indian Rupees (220 US$) is the national penalty for a person who kills an Irrawaddy dolphin in Chilika Lagoon. This policy has never been implemented as it requires monitoring by enforcing agencies at the local scale. More importantly, the strategy may create a distance between governing agencies and the local population. Fear of being imprisoned is likely to contribute to the 50% of dolphin mortalities from unknown causes (Chapter 3). Strategies which encourage fishers to be open about the mechanics of accidental by-catch might lead to greater understanding and help design effective mitigation strategies.

In 2005, a “protected area” was proposed by the Chilika Development Authority (see Chapter 2). This strategy invoked much resistance from stakeholders as the idea or design of this protected area had not been discussed with them. In February 2009, the Chilika Development Authority again proposed to designate a core dolphin area in the Outer Channel of Chilika assuming that this area would not completely exclude fishers

[7] A vote-bank is a group of voters from a single community who consistently back a certain political party. It is usually created through divisive policies and encourages voters to vote on the basis of narrow communal considerations, often causing rifts even between neighboring communities.

(Anonymous 2009). No other details are known of this proposal. A dolphin core area where boat traffic is limited could be a beneficial strategy for the Outer Channel dolphin population. I do not know if the strategy will materialize or if it has been discussed with the local stakeholders living in the Outer Channel, though it would be important to consult local stakeholders to make the strategy successful at the operative level i.e to successfully implement the strategy.

Tourism

Tourism in the Outer Channel offers trips to migratory bird sites, dolphin watching, scenic views at the sea mouth, and a visit to a temple. The most favored trips (Chapter 10) include dolphin watching. The peak season is during the months of October to January. The numbers of just one of the two tourism associations in the Outer Channel of Chilika indicated an average of 2000 boat trips per month from (Chapter 10). Thus, the dolphin-based tourism industry is economically important, providing a range of income opportunities to people from 12 villages and more than 600 families in the Outer Channel.

Results from Chapter 10, suggest that fishers involved in the tourism industry perceived movement of boat propellers and engine noise as major sources of stress to dolphins. Obstruction to dolphin movement and unsuitable habitat are perceived as the two main causes of mortality in dolphins. Entanglement in fishing nets was also perceived as causing mortality especially shore seine nets, shark nets and hook lines. Removing obstructions for free movement, following dolphin-watching guidelines and managing detrimental fishing gear are suggested as the main solutions to reduce mortality of dolphins. Conservation practitioners need to seize the opportunity to turn these perceptions into solutions. Knowledge of local perceptions and concerns can build relationships and can reduce friction between conservation practitioners and local communities through collaborative dialogue.

I used the Linkage Assessment Framework explained in Chapter 1 to compare the community-introduced alternate livelihood of tourism with fishing in the Outer Channel (Table 11.1). Livelihood from tourism has a direct linkage to biodiversity, with dolphins being the main tourist attraction. A direct linkage signifies a dependence of the tourism livelihood on dolphins. I scored the linkage between fisheries and communities in the Outer Channel region based on information from Chapter 2 and 4. I found that the strength of the tourism linkage is very close to that of the fisheries with communities (Average linkage score: 3.8) in the Outer Channel of Chilika, suggesting that tourism could substitute for fishing in the Outer Channel.

The tourism linkage is strong from an economic perspective but conservation outcomes from the linkage have not yet been realized and would require responsible social and ecological planning to make the industry sustainable. The dolphin watching industry did not develop as part of a conservation strategy and neither was it managed by government agencies during its growth. The results from Chapter 4, and 10, show that local communities are knowledgeable about the causes of mortality and sources of stress to dolphins from tourist boat traffic. The challenge facing conservation practitioners is to encourage local stakeholders to recognize the benefits from conservation goals, and the linkage between tourism livelihood and dolphin persistence. Scientific evidence of the effects of boat traffic on dolphin behavior is not available for Chilika Lagoon to help convince local stakeholders. The dissemination of results from my study, along with continuous discussions with the different groups in Chilika, could help guide future conservation initiatives.

11.4. Objective 3: An action-research model of management to implement and manage conservation strategies in Chilika

Figure 11.2, shows how different conservation strategies could be operated at the local scale in Chilika. The model depends on five main factors: trust, empowerment, collaboration, learning and respecting local knowledge (Berkes 2004). Building awareness and capacity to 'learn collaboration' for problem solving is fundamental to the model (Armitage et al. 2008). The model (Figure 11.2) does not include the existing governance bodies, to avoid a mismatch of management scales (Berkes 2004). Rather, I forsee a conservation model which functions with the support of policy makers to reduce cross-scale conflict, rather than as a top-down enforcer of protection.

Table 11.1. Ranking of the linkage between dolphins and livelihood from tourism in the Outer Channel of Chilika lagoon, India. Five linkage dimensions: A. species-livelihood dependence, B. habitat-species dependence, C. livelihood-space dependence, D. livelihood-time dependence and E. livelihood-conservation dependence are used. The scores are based on a qualitative analysis of results from Chapter 2 to10 and ranked from one (lowest strength) to five (strongest strength).

	Fishing	**Tourism**	***Rationale***
A. species-livelihood dependence	5	2	*Livelihood from fishing is not dependent only on one species of fish but on a diverse range of fish and other marine products.* Tourism mainly focuses on dolphins and bird-watching sites in Chilika.
B. habitat-species dependence	2	5	*Fish resources are spread evenly if unequally in the lagoon and fishers can move in boats to explore other fishing grounds.* The dolphins in the Outer Channel of Chilika show high site fidelity and are an easy tourist target as their locations are predictable.
C. livelihood-space dependence	5	5	*Considering the high population of fishers in Chilika, the availability of fish in the Outer Channel is crucial to sustenance.* Tourism is successful here because dolphins show high site fidelity. If the cost of showing dolphins was high, the livelihood of tourism would have been limited.
D. livelihood-time dependence	5	5	Fishing and tourism both are active occupations all through the year with peak seasons in November to March.
E. livelihood-conservation dependence	2	1	*Fisheries in Chilika are over exploited and not sustainable.* The tourism industry is mainly a source of income. It is not built on conservation goals and does not have a green market value as yet. Dolphins are famous only for their iconic value.
Average Score	**3.8**	**3.6**	

The model is divided into three phases. Each phase is in itself an adaptive cycle of action-research. Solid arrows show the flow of the process, and the non-solid arrows show the feedback of information to start a new cycle in any particular phase. Agreeing upon a conservation target and identifying a problem initiates phase I of the model and leads to the production of management plans and/or conservation actions or products with the collaboration of key stakeholders like village leaders. The agreed product would then be tested at the local scale (e.g. Outer Channel) and if stakeholder involvement is positive then the product would be adapted to the needs of other relevant communities. The outcome of the product would be measured and the cycle adapted based on the results. Outcomes would be monitored using agreed social and ecological performance indicators. Changing community attitudes towards conservation should be one of the main outcomes of such a process.

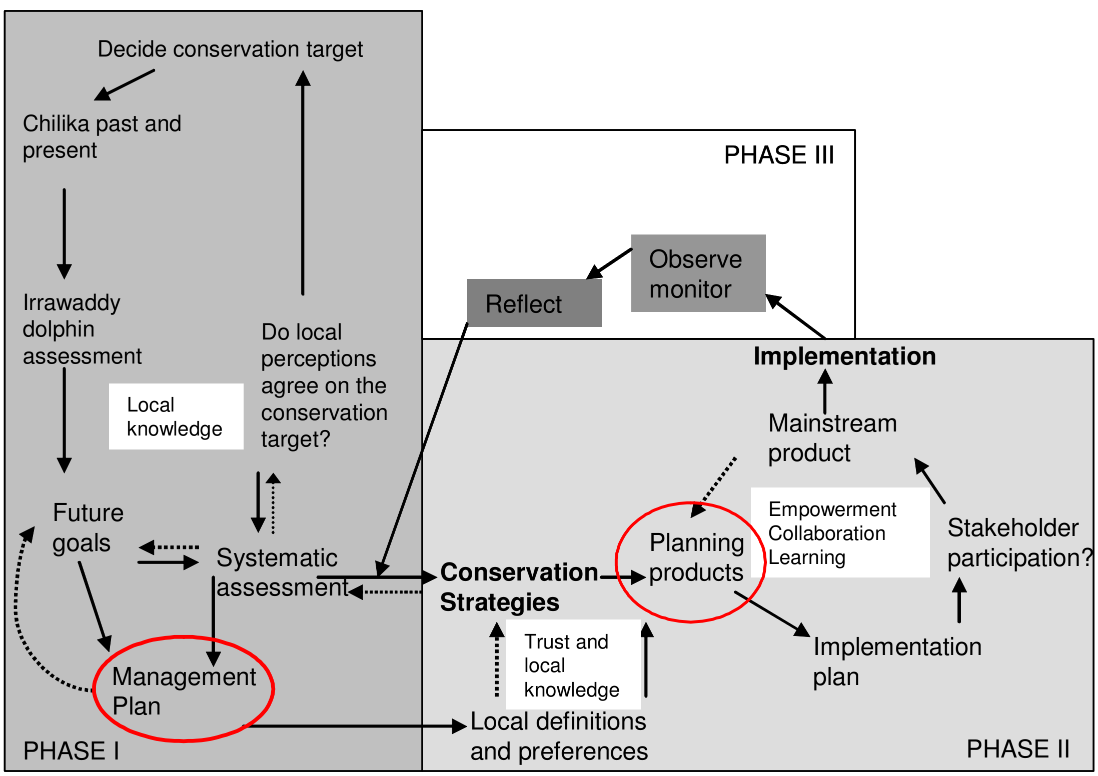


Figure 11.2. An operational model of managing strategies at the stakeholder level to support effective conservation of dolphins in Chilika Lagoon. The model shows the importance of local knowledge, trust, empowerment, learning and collaboration, and an adaptive-research cycle of discussions and learning.

11.5. Conclusions

Chilika offers a glimpse into how natural resource management is operating in human-dominated regions of the developing world. A long-term program informed by social and ecological research, using an action-research model offers potential as a future goal of conservation practice in Chilika if financial and human resources are committed to this goal over a long period of time.

Resolving the issue of dolphin mortalities in fishing nets has been on the forefront of marine mammal conservation worldwide. In places like Chilika where relocation or replacement of gear is not financially feasible and alternate livelihoods are few, this issue will not be resolved by a ban on detrimental fishing nets. It will require personal effort by the fishers to monitor nets and release dolphins. Resource enhancement techniques to help increase fish populations in the Lagoon would also help in gaining trust and managing for sustainable fisheries. Local stakeholders should also be offered a transparent and accountable process of co-management and active-research to formulate such solutions within a conservation plan.

A community-based conservation paradigm underpins the current agenda of the Chilika Development Authority (Chapter 2) (Kothari & Pathak 2006). Biodiversity conservation is but one of its many responsibilities. These responsibilities largely focus on development. Community-based conservation is based on the concept that if development and conservation could be achieved in tandem, then the interests of both could be served. If conservation goals are consistent with development goals of the relevant agency then conservation management will only require strengthening these institutions. However, this is not often the case and the results from Chilika and various other community-based conservation projects have been mixed. In Chilika, one of the main limitations to successful conservation is the mismatch between top-down ‘expert opinion’ based management decisions (Whyte 1989) and the preferences of the stakeholders who actually operate at the scale the system is being managed. The top-down conservation goals tend to be very static while the systems where these goals are meant to be achieved are complex and dynamic.

Cross scale agreements (across villages and institutions) and deliberations about conservation goals and targets, are necessary to make co-management succeed in Chilika. Berkes (2004) points out that community-based conservation is not necessarily driven by economic incentives, but more by equity and empowerment, meaning that most human communities at least at small scales (at the village level) will be ready to invest energy in changes and processes that ensure long-term social well being.

Building cross-scale capacity and awareness by adaptive learning through deliberations supported by government agencies would be a starting point for developing effective operational models of conservation. One of the most important requirements of this model is appropriate governance structures that allow flexibility in management at the ground level where conservation operates. Given the range of natural and induced ecological changes in the Chilika system in the past decades (Chapter 2), and the changes anticipated in this era of climate change, sustaining habitat quality and retaining biodiversity richness would remain a high priority of conservation planning for the Chilika system. The link between habitat restoration and economic development would be incomplete without including the sustenance of biodiversity.

I conclude that effective conservation management of endangered species in human-dominated regions requires multiple strategies with an action-research model of conservation planning. If a target species such as the Irrawaddy dolphin, is facing multiple threats and is found in small, isolated populations, the importance of habitat size, carrying capacity and habitat quality should not be underestimated. Habitat-level mitigations of threat need to be included in species conservation plans

Evaluations of the biological and the social components of the system should be used to assess if a decrease in threats is taking place and if perceptions towards dolphin conservation are changing to meet future visions. The success of conservation programs in human-dominated regions depends on the human communities living in the area, and future conservation projects should involve local stakeholders in every stage of the process. Strategies should be dynamic rather than static, and should be able to communicate long-term benefits for the ecosystem and the people. Deliberation about conservation goals with different groups of local stakeholders should be organized to enable each group to discuss concerns amongst themselves and return ideas, suggestions and opinions. Conservation practitioners should no longer ignore the interplay of power between and across levels in the social system they wish to influence. Rather they should invest effort in negotiating common goals that benefit everyone.

My thesis that the conservation of endangered species is a socio-ecological issue and that the interplay of politics and common property ownership would greatly influence conservation outcomes is supported by my results. The effective implementation of conservation models at ecologically and culturally appropriate management scales would improve the likelihood of survival of endangered species. Biological information is necessary, but not sufficient to conserve species. Rather, a multidisciplinary approach, informed by an action-research based process is required to manage endangered species in complex socio-ecological systems, such as Irrawaddy dolphins in Chilika Lagoon.

REFERENCES

Adams, W. M., R. Aveling, D. Brockington, B. Dickson, J. Elliott, J. Hutton, D. Roe, B. Vira, and W. Wolmer. 2004. Biodiversity Conservation and the Eradication of Poverty. Science **306**:1146-1149.

Adams, W. M., and J. Hutton. 2007. People, Parks and Poverty: Political Ecology and Biodiversity Conservation. Conservation and Society **5**:147-183.

Agardy, M. T. 1994. Advances in marine conservation: the role of marine protected areas. TREE **9**.

Agrawal, A., and C. C. Gibson. 1999. Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation. World Development **27**:629-649.

Agrawal, A., and E. Ostrom. 2006. Political Science and Conservation Biology: a Dialog of the Deaf. Conservation Biology **20**:681-682.

Agrawal, A., and K. H. Redford. 2006. Poverty, development and biodiversity conservation: shooting in the dark. WCS Working Paper 26 (pp50).

Ahmad, E. 1972. Coastal Geomorphology of India. Orient Longman, Delhi, India.

Akcakaya, H. R., and S. Ferson. 1999. RAMAS Red List: Threatened Species Classifications Under Uncertainty, Applied Biomathematics, New York USA.

Akcakaya, H. R., S. Ferson, M. A. Burgman, D. A. Keith, G. M. Mace, and C. R. Todd. 2000. Making Consistent IUCN Classifications under Uncertainty. Conservation Biology **14**:1001-1013.

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behaviour **49**:227-267.

Anderson, J. 1879. Anatomical and Zoological Researches: comprising an account of the zoological results of the two expeditions to Wester Yunnan in 1868 and 1875 and a Monograph of the two cetacean genera *Platanista* and *Orcella*. London, B.Quaritch.

Annandale, N. 1915. Order Cetacea. *Orcaella brevirostris* (Owen). Memoirs of the Indian Museum:166-167.

Anon. 2006. Population Census, Orissa: Government of India.

Anonymous 2006. The Wildlife (Protection) Act: 1972 as amended up to 2006. Natraj Publishers, Dehradun, India.

Anonymous. 2008. 'Snubby' study splashes ahead. Australian Geographic downloaded on June 12th 2008 from http://editorial.australiangeographic.com.au news Australia.

Anonymous. 2009. A core area to protect dolphins, boatmen. New Indian Express, Bhubhaneswar, February 5th 2009.

Armitage, D., M. Marschke, and R. Plummer. 2008. Adaptive co-management and the paradox of learning. Global Environmental Change **18**:86-98.

Armsworth, P. R., K. M. A. Chan, G. C. Daily, P. R. Ehrlich, C. Kremen, T. H. Ricketts, and M. A. Sanjayan. 2007. Ecosystem-Service Science and the Way Forward for Conservation. Conservation Biology **21**:1383-1384.

Arnold, P., W., and G. E. Heinsohn. 1996. Phylogenetic Status of the Irrawaddy Dolphin *Orcaella brevirostris* (Owen in Gray): A Cladistic Analysis. Memoirs of the Queensland Museum **39**:141-204.

Arnold, P. W. 2002. Irrawaddy Dolphin, *Orcaella brevirostris* Pages Pp. 435-438 in W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of Marine Mammals. Academic Press, San Diego.
Axelrod, R., and W. D. Hamilton. 1981. The evolution of cooperation. Science **211**:1390-1396.
Ayyeppan, S., and J. K. Jena. 2000. Coastal fisheries in Orissa, an important economic activity. In V. K. E. Sharma, editor Environmental Problems of Coastal Areas in India. Bookwell, Delhi.
Baird, I. G., and B. Mounsouphom. 1997. Distribution, mortality, diet and conservation of Irrawaddy dolphins (*Orcaella brevirostris* Gray) in Lao PDR. Asian Marine Biology **14**:41-48.
Baird, I. G., and I. L. Beasley. 2005. Irrawaddy dolphin *Orcaella brevirostris* in the Cambodian Mekong River: an initial survey. Oryx **39**:301-310.
Baird, R. W., and H. Whitehead. 2000. Social organization of mammal-eating killer whales: group stability and dispersal patterns. Canadian Journal of Zoology **78**:2096-2105.
Barnes, L. G., D. P. Domning, and C. E. Ray. 1985. Status of studies on fossil marine mammals. Marine Mammal Science 1: 15-53
Bautista, A. L. S. 2000. A preliminary survey on the habitat of the Irrawaddy dolphin (*Orcaella brevirostris*) in Malampaya Sound, Palawan. Page 77. College of Veterinary Medicine. University of the philippines Los Banos.
Bawa, K. S., R. Seidler, and P. H. Raven. 2004. Reconciling Conservation Paradigms. Conservation Biology **18**:859-860.
Bawa, K. S. 2006. Hurdles for conservation science in India. Current Science **91**:1005.
BCN. 1999. Biodiversity Conservation Network: Evaluating linkages between business, the environment, and local communities. Biodiversity Support Program, Washington, D.C. Available from www.BCNet.org or www.BSPonline.org
Beasley, I., S. Chooruk, and N. Piwpong. 2002a. The status of the Irrawaddy dolphin, *Orcaella brevirostris*, in Songkhla Lake, Southern Thailand. Pages 75-84 in T. Jefferson, A., and B. D. Smith, editors. Facultative Freshwater Cetaceans of Asia: Their Ecology and Conservation. Raffles Bulletin of Zoology. Supplement No. 10.
Beasley, I., P. Arnold, and G. Heinsohn. 2002b. Geographical variation in skull morphology of the Irrawaddy dolphin *Orcaella brevirostris* (Owen in Gray, 1866). Pages 15-34 in T. Jefferson, A., and B. D. Smith, editors. Facultative Freshwater Cetaceans of Asia: Their Ecology and Conservation. The Raffles Bulletin of Zoology. Supplement No. 10.
Beasley, I., K. M. Robertson, and P. Arnold. 2005. Description of a new dolphin, the Australian Snubfin dolphin *Orcaella Heinsohni* sp. N. (Cetacea, Delphinidae). Marine Mammal Science **21**:365-400.
Beasley, I., Somany, P., Gilbert, M., Phothitay, C., Saksang, Y., San Lor, K. and Sokha, K. 2007. Review of the Status and Conservation of Irrawaddy Dolphins *Orcaella brevirostris* in the Mekong River of Cambodia, Lao PDR and Vietnam. Pages 67-82 in B. D. Smith, Shore R. G and Lopez, A, editors. Status and conservation of freshwater populations of Irrawaddy dolphins. WCS, Pnom Penh.
Beasley, I. 2008. Conservation of the Irrawaddy dolphin *Orcaella brevirostris* (Owen in Gray 1866) in the Mekong River: Biological and Social considerations influencing

managment. School of Earth and Environmental Sciences. James Cook University, Townsville.
Bejder, L., A. Samuels, H. Whitehead, and N. Gales. 2006a. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Animal Behaviour **72**:1149-1158.
Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty, and M. Krutzen. 2006b. Decline in Relative Abundance of Bottlenose Dolphins Exposed to Long-Term Disturbance. Conservation Biology **20**:1791-1798.
Berkes, F., and C. Folke 1998. Linking Social and Ecological Systems:Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press.
Berkes, F. 2004. Rethinking Community-Based Management. Conservation Biology **18**:621-630.
Borchers, D. L., S. T. Buckland, and W. Zucchini 2002. Estimating Animal Abundance Closed Populations. Springer-Verlag London.
Bradshaw, C. J. A., H. F. Mollet, and M. G. Meekan. 2007. Inferring population trends for the world's largest fish from mark-recapture estimates of survival. Journal of Animal Ecology **76**:480-489.
Braeger, S., A. Chong, S. Dawson, E. Slooten, and B. Wursig. 1999. A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins. Helgoland Marine Research. **53**(2):122-128.
Braeger, S., and K. Schneider. 1998. Near-shore distribution and abundance of dolphins along the West Coast of the South Island, New Zealand. New Zealand Journal of Marine & Freshwater Research. **32**(1): 105-112.
Brandon, K., K. H. Redford, and S. E. Sanderson 1998. Parks in peril people politics and protected areas. Island Press, Washington DC.
Brandon, K. E., and M. Wells. 1992. Planning for people and parks: Design dilemmas. World Development **20**:557-570.
Breiman, L., J. H. Friedman, R. A. Olshen, and C. J. Stone 1984. Classification and Regression Trees, Wadsworth, Belmont, California, 367pp.
Bright, A. D., M. J. Manfredo, and D. C. Fulton. 2000. Segmenting the Public: An Application of Value Orientations to Wildlife Planning in Colorado. Wildlife Society Bulletin **28**:218-226.
Brooks, T., A. B. D. F. Gustavo, and A. S. L. Rodrigues. 2004. Species, Data, and Conservation Planning. Conservation Biology **18**:1682-1688.
Buccat, M. C. 2000. A preliminary investigation on the population distribution of Irrawaddy Dolphin (*Orcaella brevirostris*) in Malampaya Sound, Palawan. Page 49. Faculty of the College of Veterinary Medicine. University of Philippines at Los Banos Laguna.
Buckland, S. T., D. R. Anderson, K. P. Burham, and J. L. Laake 1993. Distance Sampling: Estimating abundance of biological populations. Chapman and Hall.
Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas 2001. Introduction to Distance sampling-Estimating abundance of biological populations. Oxford University Press, New York.

Bunce, L., and B. Pomeroy 2003. Socioeconomic Monitoring Guidelines for Coastal Managers in Southeast Asia. Page 82 pp. World Commission on Protected Areas and Australian Institute of Marine Science.

Burgman, M. A., and J. C. Fox. 2003. Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. Animal Conservation **6**:19-28.

Burnham, K. P., and D. R. Anderson 1998. Model selection and inference: a practical information theoretic approach. Springer-Verlag New York.

Byers, J. A., and D. W. Kitchen. 1988. Mating system shift in a pronghorn population. Behavioral Ecology and Sociobiology **22**:355-360.

Cairns, S. J., and S. J. Schwager. 1987. A comparison of association indices. Animal Behaviour **35**:1454-1469.

Calambokidis, J., and J. Barlow. 2004. Abundance of Blue and Humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science **20**:63-85.

Carlsson, L., and F. Berkes. 2005. Co-management: concepts and methodological implications. Journal of Environmental Management **75**:65–76.

Carr, M. 2000. Marine protected areas: challenges and opportunities for understanding and conserving coastal marine ecosystems. Environmental Conservation **27**:106-109.

CDA. 2007. Annual Population Census of Irrawaddy dolphins in Chilika lagoon – 2007. http://www.chilika.com/news.htm, Bhubhaneswar, India.

Chapman, C. A., L. J. Chapman, and R. W. Wrangham. 1995. Ecological constraints on group size: an analysis of spider monkey and chimpanzee subgroups. Behavioral Ecology and Sociobiology **36**:59-70.

Chilvers, B. L., and P. Corkeron. 2002. Association patterns of bottlenose dolphins (*Tursiops aduncus*) off Point Lookout, Queensland, Australia Canadian Journal of Zoology **80**:973-979.

Chivers, S. J. 2002. Cetacean life-history. Pages 221-225 in W. F. Perrin, Würsig, B., and Thewissen, H editors. Encyclopedia of Marine Mammals. Academic Press, San Diego, CA.

Clutton-Brock, T. H. 1974. Primate social organisation and ecology. Nature **250**:539-542.

Clutton-Brock, T. H. 1989. Mammalian mating systems. Proceedings of the Royal Society of London. Series B. Biological sciences **236**:339-372.

Conforti, V. A., and F. Cesar Cascelli de Azevedo. 2003. Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguaçu National Park area, south Brazil. Biological Conservation **111**:215-221.

Connor, R. C., R. A. Smolker, and A. F. Richards. 1992. Two Levels of Alliance Formation among Male Bottlenose Dolphins *Tursiops*-Sp. Proceedings of the National Academy of Sciences of the United States of America **89**:987-990.

Connor, R. C., and M. R. Heithaus. 1996. Approach by Great White Shark elicits flight response in Bottlenose dolphins. Marine Mammal Science **12**:602-606.

Connor, R. C., Wells, R.S., Mann, J., and Read, A.J. 2000. The bottlenose dolphin: social relationships in a fission–fusion society. Pages 91-126 in R. C. Connor. J. Mann, P. Tyack, and H. Whitehead., editors. Cetacean societies: field studies of dolphins and whales. University of Chicago Press, Chicago.

Constantine, R. 1999. Effects of tourism on marine mammals in New Zealand. Science for Conservation. Department of Conservation, Wellington, New Zealand

Cowling, R. M., A. T. Knight, D. P. Faith, S. Ferrier, A. T. Lombard, A. Driver, M. Rouget, K. Maze, and P. G. Desmet. 2004. Nature Conservation Requires More than a Passion for Species. Conservation Biology **18**:1674-1676.

Crook, J. H., and J. S. Gartlan. 1966. Evolution of primate societies. Nature **210**:1200-1203.

Crook, J. H. 1970. The socio-ecology of primates. Social Behaviour in Birds and Mammals: 103-166.

Dawson, S., P. Wade, E. Slooten, and J. Barlow. 2008. Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. Mammal Review **38**:19-49.

De Silva, P. H. D. H. 1987. Cetaceans (whales, dolphins and porpoises) recorded off Ski Lanka, India, from the Arabian Sea and Gulf, Gulf of Aden and from the Red Sea. Journal of the Bombay Natural History Society **84**:505-525.

Dhandapani, P. 1997. The conservation of the potentially endangered Irrawaddy river dolphin *Orcaella brevirostris* in Chilika Lagoon, Orissa, India. Journal Bombay Natural History Society **94**:536-539.

DOF. 1998. Handbook on Fisheries Statistics of Orissa, 1996-97 Directorate of Fisheries, Government of Orissa.

Dolar, L. M. 1999. A survey of cetaceans and fishery interactions in the northwestern Sulu Sea and Malampaya Sound, Philippines. Pages 1-53. World Wildlife Fund, US, Dumaguete City.

Donoghue, M. 1996. The New Zealand experience - One country's response to cetacean conservation. . Pages 423-445 in M. P. Simmonds, and J. D. Hutchinson, editors. The conservation of whales and dolphins: Science and practice. John Wiley & Sons, New York.

Elgar, M. A. 1989. Predator vigilance and group size in mammals and birds: A critical review of the empirical evidence. Biological Reviews **64**:13-33.

Emlen, S. T., and L. W. Oring. 1977. Ecology, sexual selection, and the evolution of mating systems. Science **197**:215-223.

Finlayson, C. M., N. Khurshid, S. Kaul, A. K. Pattnaik, and C. L. Trisal. 2001. Removal of Chilika Lake Ramsar Site, India, from the Montreux Record 9-13 December 2001. Page 18. Ramsar Advisory Mission No. 50: India (2001). The Ramsar Convention on Wetlands.

Gärdenfors, U. 2001. Classifying threatened species at national versus global levels [Review]. Trends in Ecology & Evolution **16**:511-516.

Gaston, K. J. 1991. How Large Is a Species' Geographic Range? Oikos **61**:434-438.

Gaston, K. J. 1994. Measuring Geographic Range Sizes. Ecography **17**:198-205.

Geist, V. 1974. On the Relationship of Social Evolution and Ecology in Ungulates. Amer. Zool. **14**:205-220.

Gero, S., L. Bejder, H. Whitehead, J. Mann, and R. C. Connor. 2006. Behaviourally specific preferred associations in bottlenose dolphins, *Tursiops* spp. Canadian Journal of Zoology **83**:1566-1573.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology **68**:1634-1372.

Gerrodette, T. 1993. TRENDS: Software for a Power Analysis of Linear Regression. Wildlife Society Bulletin **21**:515-516.
Getz, W. M., and C. C. Wilmers. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography **27**:489-505.
Ghosh, A. K., A. K. Pattnaik, and T. J. Ballatore. 2006. Chilika Lagoon: Restoring ecological balance and livelihoods through re-salinization. Lakes & Reservoirs: Research & Management **11**:239-255.
Gibson, Q. A., and J. Mann. 2009. Do sampling method and sample size affect basic measures of dolphin sociality? Marine Mammal Science **25**:187–198
Ginsberg, J., and D. Rubenstein. 1990. Sperm competition and variation in zebra mating behavior. Behavioral Ecology and Sociobiology **26**:427-434.
Gordon, H. S. 1954. The economic theory of a Common Property Resource: The Fishery. Journal of Political Economy **62**:124-142.
Gormley, A. M., S. A. Dawson, E. Slooten, and S. Brager. 2005. Capture-recapture estimates of Hector's dolphin abundance at Banks Peninsula, New Zealand. Marine Mammal Science **21**:204-216.
Gossling, S. 1999. Ecotourism: a means to safeguard biodiversity and ecosystem functions? Ecological Economics **29**:303–320.
Gowans, S., B. Wursig, and L. Karczmarski. 2008. The social structure and strategies of delphinids: Predictions based on an ecological framework. Advances in Marine Biology **53**:195-294.
Gretarsdottir, S., and A. Ulfur. 1992. Evolution of the common cetacean highly repetitive DNA component and the systematic position of *Orcaella brevirostris*. Journal of Molecular Evolution **34**:201-208.
Groves, C. R., D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for Biodiversity Conservation: Putting Conservation Science into Practice. BioScience **52**:499-512.
Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A Global Map of Human Impact on Marine Ecosystems. Science **319**:948-952.
Hammond, P. S., P. Berggren, H. Benke, D. L. Borchers, A. Collet, M. P. Heide-Jorgensen, S. Heimlich, A. R. Hiby, M. F. Leopold, and N. Oien. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology **39**:361-376.
Hardin, G. 1968. The Tragedy of the Commons Science **162**:1243-1248.
Harding, D. M. 1984. Assessing tropical forest lands: Their suitability for sustainable uses in R.C. Carpenter (Editor). East West Centre (Hawaii), Natural Resources and the Environment Series, 3. Tycooly International Publishing Company Ltd., Dublin, Ireland, 1981.
Herzing, D. L., and B. J. Brunnick. 1997 Coefficients of Association of reproductively active female Atlantic spotted dolphins, *Stenella frontalis*. Aquatic Mammals **23**:155-162.
Hinde, R. A. 1976. Interactions, relationships and social structure. Man **11**:1-17.

Hines, E., M. Charuchinda, S. Manananansap, A. Ilangakoon, and L. Ponnampalam. 2008. Irrawaddy Dolphins (*Orcaella brevirostris*) in Trat Province, Eastern Thailand (2007-2008). Page 19. Office of the National Research Council of Thailand.
Holdgate, M. W. 1999. The Green Web: A Union for Conservation. Earthscan, London.
Hooge, P. N., W. M. Eichenlaub, and E. K. Solomon. 1997. Using GIS to analyse animal movements in the marine environment. Animal movement extension to arcview ver 3.1. U.S. Geological Survey, Anchorage, AK, USA, Alaska Biological Science Centre.
Hoyt, E. 2001. Whale watching 2001: Worldwide tourism numbers, expenditures and expanding socio-economic benefits. Pages i–vi; 1–158. International Fund for Animal Welfare, Yarmouth Port, MA, USA.
Hoyt, E. 2005. Marine protected areas for whales, dolphins and porpoises: a world handbook for cetacean habitat conservation. Earthscan, London.
IANS. 2008. Irrawaddy Dolphins number goes up in Orissa. Kalinga Times Bhubhaneswar, February 27th 2008.
IANS. 2009. Population of endangered dolphin rises in Orissa's Chilika Lake. Bhubhaneswar, February 20th 2009.
Ilangakoon, A. D., D. Sutaria, E. Hines, and R. Raghavan. 2008. Community interviews on the status of the dugong (*Dugong dugon*) in the Gulf of Mannar (India and Sri Lanka). Marine Mammal Science **24**:704-710.
IUCN. 1994. Guidelines for protected area management categories. Cambridge UK:IUCN.
IUCN 2000. 2000 IUCN Red List of Threatened Species, Gland, Switzerland.
IUCN 2002. 2002 IUCN Red List of Threatened Species, Gland, Switzerland.
IUCN. 2003. Guidelines on the application of the IUCN Red List Criteria at national or regional levels: Version 3.0. Page ii + 26pp, IUCN Species Survival Commission. Gland, Switzerland and Cambridge,UK
IUCN 2004. 2004 IUCN Red List of Threatened Species, Gland, Switzerland.
IUCN. 2006a. Guidelines for Using the IUCN Red List Categories and Criteria: Version 6.1. Prepared by the Standards and Petitions Working Group for the IUCN SSC Biodiversity Assessments Sub-Committee in July 2006. Downloadable from http://app.iucn.org/webfiles/doc/SSC/RedList/RedListGuidelines.pdf.
IUCN. 2006b. Scoping mission to the Dhamra Port project. Business and Biodiversity Program, Asia. The World Conservation Union (IUCN).
IUCN 2006c. 2006 IUCN Red List of Threatened Species Gland, Switzerland.
IUCN 2007. 2007 IUCN Red List of Threatened Species Gland, Switzerland.
James, P. S. B. R., M. Rajagopalan, S. S. Dan, A. Bastian Fernando, and V. Selvaraj. 1989. On the mortality and stranding of marine mammals and turtles at Gahirmatha, Orissa from 1983 to 1987. Journal of the Marine Biological Association of India **31**:28-35.
Jarman, P. J. 1974. The Social Organisation of Antelope in Relation to Their Ecology. Behaviour **48**:215-267.
Jefferson, T. A. 2000. Population biology of the Indo-Pacific hump-backed dolphin in Kong Kong waters. Wildlife Monographs (Supplement to The Journal of Wildlife Management) **144**:1-68.

Jefferson, T. A., S. K. Hung, and B. Würsig. 2009. Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong. Marine Policy **33**:305-311.

Jenkins, R. E., R. D. H. Brown, and M. R. Phillips. 2009. Harbour porpoise (*Phocoena phocoena*) conservation management: A dimensional approach. Marine Policy **33**:doi:10.1016/j.marpol.2009.1002.1003.

Jentoft, S., B. J. McCay, and D. C. Wilson. 1998. Social theory and fisheries co-management. Marine Policy **22**:423-436.

Johns, A., and J. Skorupa. 1987. Responses of rain-forest primates to habitat disturbance: A review. International Journal of Primatology **8**:157-191.

Kadekodi, G. 2000. India: Chilika Lake. Pages 213-230 in Alexander Wood, P. Stedman-Edwards, and J. Mang, editors. The Root Causes of Biodiversity Loss. Earthscan, London.

Kalpavriksh. 2005. Dolphin Sanctuary proposed in Chilika. Protected Area Update **11**.

Kannan, K., K. Ramu, N. Kajiwara, R. K. Sinha, and S. Tanabe. 2005. Organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers in Irrawaddy dolphins from India. Archives of Environmental Contamination & Toxicology **49**:415-420.

Karanth, K. U., and M. D. Madhusudan. 1997. Avoiding Paper Tigers and Saving Real Tigers: Response to Saberwal. Conservation Biology **11**:818-820.

Keith, D. A., M. A. McCarthy, H. Regan, T. Regan, C. Bowles, C. Drill, C. Craig, B. Pellow, M. A. Burgman, L. L. Master, M. Ruckelshaus, B. Mackenzie, S. J. Andelman, and P. R. Wade. 2004. Protocols for listing threatened species can forecast extinction. Ecology Letters **7**:1101-1108.

Kindvall, O., and U. Gardenfors. 2003. Temporal extrapolation of PVA results in relation to the IUCN Red List criterion E. Conservation Biology **17**:316-321.

Kittiwattanawong, K., Chantraporsyl, S., Ninwat, S. and Chooruk,S. 2007. Review of the Status and Conservation of Irrawaddy Dolphins *Orcaella brevirostris* in Songkhla Lake of Thailand. Pages 83-89 in B. D. Smith, Shore R. G and Lopez, A, editor. Status and Conservation of Freshwater Irrawaddy dolphins. WCS, Pnom Penh.

Klingel, H. 1998. Observations on social organization and behaviour of African and Asiatic Wild Asses (*Equus africanus* and *Equus hemionus*). Applied Animal Behaviour Science **60**:103-113.

Knight, T.A., J. Smith, and S. Cropper. 2001. Developing sustainable collaboration: learning from theory and practice. Primary Health Care Research & Development **2**:139-148.

Knight, T. A., M. R. Cowling, and M. B. Campbell. 2006. An Operational Model for Implementing Conservation Action. Conservation Biology **20**:408-419.

Kothari, A., and N. Pathak. 2006. Protected Areas, Community based participation and decentralisation: Lessons from India. A report prepared for the Ecosystems, Protected Areas, and People Project (EPP) of the IUCN World Commission on Protected Areas.

Krause, J., and G. D. Ruxton 2002. Living in Groups Oxford University Press, Oxford

Kreb, D. 2000. Conservation of the Pesut, *Orcaella brevirostris* in the Mahakam River and Lakes, East Kalimantan, Indonesia. University of Amsterdam.

Kreb, D. 2002. Density and abundance of the Irrawaddy dolphin, *Orcaella brevirostris*, in the Mahakam River of East Kalimantan, Indonesia: A comparison of survey techniques. Pages 85-96 in T.A. Jefferson., and B. D. Smith, editors. Facultative Freshwater Cetaceans of Asia: Their Ecology and Conservation. The Raffles Bulletin of Zoology. Supplement No. 10.

Kreb, D., Budiono., and Syachraini. 2007. Review of the Status and Conservation of Irrawaddy Dolphins *Orcaella brevirostris* in the Mahakam River of Indonesia. Pages 53-66 in B. D. Smith, Shore R. G and Lopez, A, editor. Status and conservation of freshwater populations of Irrawaddy dolphins. WCS, Pnom Penh.

Kreb, D. and B. D.Smith. 2007. *Orcaella brevirostris* (Mahakam subpopulation). In: IUCN 2007 2007 IUCN Red List of Threatened Species <www.iucnredlist.org>. Downloaded on 01 January 2008.

Kruuk , H. 1972. The spotted hyena: a study of predation and social behavior. University of Chicago Press, Chicago.

Kumar, S., K. C. Pathak, P. Pedneker, N. S. N. Raju, and R. Gowthaman. 2006. Coastal processes along the Indian coastline. Current Science **91**:530-536.

Kumaran, P. L. 2002. Marine Mammal Research in India - a review and critique of the methods. Current Science **83**:1210-1220.

Laake, J. L., J. Calambokidis, S. D. Osmek, and D. L. Rugh. 1997. Probability of detecting harbor porpoise from aerial surveys: estimating g(0). Journal of Wildlife Management **61**:63-75.

Lamb, B. L., and K. Cline. 2003. Public Knowledge and Perceptions of Black-Tailed Prairie Dogs. Human Dimensions of Wildlife **8**:127 - 143.

Leighten, M. 1986. Hornbill Social Dispersion: Variations on a Monogamous Theme in D. I. Rubenstein, and R. W. Wrangham, editors. Ecological Aspects of social evolution. Princeton University Press, New Jersey.

Leopold, A 1939. A Biotic view of land. Journal of Forestry **37**(9): 727-730

Linkie, M., Y. Dinata, A. Nugroho, and I. A. Haidir. 2007. Estimating occupancy of a data deficient mammalian species living in tropical rainforests: Sun bears in the Kerinci Seblat region, Sumatra. Biological Conservation **137**:20-27.

Lott, D. F. 1984. Intraspecific Variation in the Social Systems of Wild Vertebrates. Behaviour **88**:266-325.

Lusseau, D., K. Schneider, O. J. Boisseau, P. Haase, E. Slooten, and S. M. Dawson. 2003. The bottlenose dolphin community of Doubtful Sound features a large proportion of long-lasting associations. Behavioral Ecology and Sociobiology **54**:396-405.

Mace, G. M., and R. Lande. 1991. Assessing Extinction Threats: Toward a Reevaluation of IUCN Threatened Species Categories. Conservation Biology **5**:148-157.

MacKenzie, D. I., J. D. Nichols, A. J. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines 2006. Occupancy estimation and modeling-Inferring patterns and dynamics of species occurence. Elsevier Academic Press.

Madhupratap, M., M. Gauns, N. Ramaiah, S. Prasanna Kumar, P. M. Muraleedharan, S. N. de Sousa, S. Sardessai, and U. Muraleedharan. 2003. Biogeochemistry of the Bay of Bengal: physical, chemical and primary productivity characteristics of the central and western Bay of Bengal during summer monsoon 2001. Deep Sea Research Part II: Topical Studies in Oceanography **50**:881-896.

Madhusudan, M. D., and T. R. Shankar Raman. 2003. Conservation as if Biological Diversity Matters: Preservation versus Sustainable Use in India. Conservation and Society **1**:49-59.

Madhusudan, M. D., K. Shanker, A. Kumar, C. Mishra, A. Sinha, R. Arthur, A. Datta, M. Rangarajan, R. Chellam, G. Shahabuddin, R. Sankaran, M. Singh, U. Ramakrishnan, and P. Rajan. 2006. Science in the wilderness: the predicament of scientific research in India's wildlife reserves. Current Science **91**:1015-1019.

Maher, C. R., and D. F. Lott. 1995. Definitions of territoriality used in the study of variation in vertebrate spacing systems. Animal Behaviour **49**:1581-1597.

Maher, C. R., and D. F. Lott. 2000. A Review of Ecological Determinants of Territoriality within Vertebrate Species. American Midland Naturalist **143**:1-29.

Mann, J. 1999. Behavioral sampling methods for cetaceans: A review and critique. Marine Mammal Science **15**:102-122.

Margules, C. R., and R. L. Pressey. 2000. Systematic Conservation Planning. Nature **405**: 243 -253.

Mark Infield, A. N. 2001. Community attitudes and behaviour towards conservation: an assessment of a community conservation programme around Lake Mburo National Park, Uganda. Oryx **35**:48-60.

Marsh, H., and D. F. Sinclair. 1989. An experimental evaluation of dugong and sea turtle aerial survey techniques. Australian Wildlife Research **16**:639-650.

Marsh, H., R. Lloze, G. E. Heinsohn, and T. Kasuya. 1989. Irrawaddy dolphin *Orcaella brevirostris* (Gray, 1866). Pages 101-118 in S. H. Ridgeway, and R. J. Harrison, editors. Handbook of Marine Mammals. Academic Press, London.

Marsh, H., A. N. M. Harris, and I. R. Lawler. 1997. The sustainability of the indigenous dugong fishery in Torres strait, Australia Papua New Guinea. Conservation Biology **11**:1375-1386.

Marsh H, Arnold P, Freeman M, Haynes D, Read A, Reynolds J, Kasuya T (2003) Strategies for conserving marine mammals. In: Gales N, Hindell M, Kirkwood R (eds) Marine mammals: fisheries, tourism and management issues. CSIRO Publishing, Collingwood, p 1–19

McCarthy, M. A., S. J. Andelman, and H. P. Possingham. 2003. Reliability of Relative Predictions in Population Viability Analysis. Conservation Biology **17**:982-989.

Martinez-Aliers, J. 2002. The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation. Edward Elgar Publishing Ltd, UK.

Mascia, M. B., J. P. Brosius, T. A. Dobson, B. C. Forbes, L. Horowitz, M. A. McKean, and N. J. Turner. 2003. Conservation and the Social Sciences. Conservation Biology **17**:649-650.

Mathevet, R., and A. Mauchamp. 2005. Evidence-based conservation: dealing with social issues. Trends in Ecology & Evolution **20**:422-423.

Mathew, S. 2004. Socio-economic aspects of management measures aimed at controlling sea turtle mortality: a case study of Orissa, India Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context. FAO Fisheries Report. No. 738, Suppl. 238p. FAO, Rome.

McLean, J., Str, Aelig, and S. De. 2003. Conservation, Relocation, and the Paradigms of Park and People Management--A Case Study of Padampur Villages and the Royal Chitwan National Park, Nepal. Society and Natural Resources **16**:509-526.

Medina-Vogel, G., L. O. Merino, R. Monsalve Alarcon, and J. D. A. Vianna. 2008. Coastal-marine discontinuities, critical patch size and isolation: implications for marine otter conservation. Animal Conservation **11**:57-64.
Miller, H. 1997 Of dolphins and deluges. Madras Musings **5**.
MoEF 1999 Ministry of Environment and Forests, Government of India www.envfor.nic.in
MoEF 2001 Ministry of Environment and Forests, Government of India www.envfor.nic.in
Molur, S., P. Nameer, O, and S. Walker. 1998. Report of the workshop Conservation Assessment and Management Plan for mammals of India BCPP-endangered species project. . Zoo Outreach Organisation, CBSC, Coimbatore, India.
Murray, T. R. 2003. Blending qualitative and quantitative research methods in theses and dissertations. Corwin Press Inc, California.
Nicholson, E., M. I. Westphal, K. Frank, W. A. Rochester, R. L. Pressey, D. B. Lindenmayer, and H. P. Possingham. 2006. A new method for conservation planning for the persistence of multiple species. Ecology Letters **9**:1049-1060.
Ostrom, E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.
Ostrom, E., J. Burger, C. B. Field, R. B. Norgaard, and D. Policansky. 1999. Revisiting the Commons: Local Lessons, Global Challenges. Science **284**:278-282.
Otis, D. L., Burnham, K.P., White,G.C. and Anderson, D.R. 1978. Statistical inference from capture data on closed animals populations. Wildlife Monographs **62**:1-135.
Ottensmeyer, C. A., and H. Whitehead. 2003. Behavioural evidence for social units in long-finned pilot whales. Canadian Journal of Zoology **81**:1327-1338.
Owen, R. 1866. The Comparative Anatomy and Physiology of Vertebrates. London
Owen, E. C. G., S. Hofmann, and R. S. Wells. 2002. Ranging and social association patterns of paired and unpaired adult male bottlenose dolphins, *Tursiops truncatus*, in Sarasota, Florida, provide no evidence for alternative male strategies. Canadian Journal of Zoology **80**:2072-2089.
Packer, C. 1986. The Ecology of Sociality in Felids in D. I. Rubenstein, and R. W. Wrangham, editors. Ecological Aspects of Social Evolution. Princeton University Press, New Jersey.
Pandav, B., B. C. Choudhury, and C. S. Kar. 1997. Mortality of olive ridley turtles *Lepidochelys olivacea* due to incidental capture in fishing nets along the Orissa coast, India. Oryx **31**:32-36.
Parra, G. J., C. Azuma, A. R. Preen, P. J. Corkeron, and H. D. Marsh. 2002. Distribution of Irrawaddy dolphins, *Orcaella brevirostris*, in Australian waters. The Raffles Bulletin of Zoology **10**:141-154.
Parra, G. J. 2005. Behavioural ecology of Irrawaddy, *Orcaella brevirostris* (Owen in Gray, 1866), and Indo-Pacific humpback dolphins, *Sousa chinensis* (Osbeck, 1765), in northeast Queensland, Australia: a comparative study Page 358. Tropical Environment Studies and Geography. James Cook University, Townsville, Australia.
Parra, G. J., P. J. Corkeron, and H. Marsh. 2006. Population sizes, site fidelity and residence patterns of Australian snubfin and Indo-Pacific humpback dolphins: Implications for conservation. Biological Conservation **129**:167-180.

Parra, G. J., R. S. Schick, and P. J. Corkeron. 2006. Spatial distribution and environmental correlates of Australian snubfin and Indo-Pacific humpback dolphins. Ecography **29**:396-406.

Parsons, C. M. 1998. Observations of Indo-pacific Humpbacked dolphins, *Sousa chinensis*, from Goa, Western India. Marine Mammal Science **14**:166-170.

Pattnaik, A. K., Sutaria, D., Khan,M., and Behera,B. 2007. Review of the Status and Conservation of Irrawaddy Dolphins *Orcaella brevirostris* in Chilika Lake of India. In Status and conservation of freshwater populations of Irrawaddy dolphins pgs 41-52. Wildlife Conservation Society, Pnom Penh.

Pernetta, J. C. 1993. Marine protected area needs in the South Asia seas region: Development of a system. . A marine conservation and development report. . IUCN Gland, Switzerland. 42 pages.

Perrin, W. F., Donovan, and J. Barlow. 1994. Report of the workshop on mortality of cetaceans in passive fishing nets and traps. Report of the International Whaling Commission **Special issue 15**:7-57.

Pilleri, G., and M. Gihr. 1974. Contribution to the knowledge of the cetaceans of southwest and monsoon Asia (Persian Gulf, Indus Delta, Malabar, Andaman Sea and Gulf of Siam). Investigations on Cetacea **5**:95-150.

Pinkerton, E. 1999. Factors in overcoming barriers to implementing co-management in British Columbia salmon fisheries. Conservation Ecology 3(2): 2. [online] URL: http://www.consecol.org/vol3/iss2/art2/

Plummer, R., C. Kulczycki, and C. Stacey. 2006. Assessing Collaborative Arrangements in Nature-based Tourism. Current Issues in Tourism **9**:499-515.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical Inference for Capture-Recapture Experiments. Wildlife Monographs **107**:1-98.

Pollock, K. H., H. D. Marsh, I. R. Lawler, and M. W. Alldredge. 2006. Estimating Animal Abundance in Heterogeneous Environments: An Application to Aerial Surveys for Dugongs. Journal of Wildlife Management **70**:255-262.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. 65–110. In: Research Techniques in Animal Ecology: Controversies and Consequences Boitani, L. and T. Fuller, editors. eds. Columbia University Press. New York.

Possingham, H. P., D. B. Lindenmayer, and T. W. Norton. 1993. A framework for the improvement of threatened species based on population viability analysis (PVA). Pacific Conservation Biology **1**:38-45.

Pressey, R. L., and A. O. Nicholls. 1989. Efficiency in conservation evaluation: scoring versus iterative approaches. Biological Conservation **50**:199-218.

Purvis, A., J. L. Gittleman, G. Cowlishaw, and G. M. Mace. 2000. Predicting extinction risk in declining species. Proc. R. Soc. London. **267**:1947-1952.

Quintana-Rizzo, E., and R. S. Wells. 2001. Resighting and association patterns of bottlenose dolphins (*Tursiops truncatus*) in the Cedar Keys, Florida. Canadian Journal of Zoology **79**: 447-456.

R Development Core Team. 2005. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org.

Rajawat, A. S., Y. Pradhan, and N. S. 2002. Coastal processes along the Indian Coast-case studies based on synergistic use of IRS-P4 OCM and IRS-1C/1D data. Proc. IAPRS & SYS on Resource and Environmental monitoring, **34**:1437-1442

RAMSAR. 2008. The Montreux Record-Keys documents of the RAMSAR convention. Ramsar Convention Secretariat, Gland, Switzerland.

Rangarajan, M., and G. Shahabuddin. 2006. Displacement and Relocation from Protected Areas:Towards a Biological and Historical Synthesis. Conservation and Society **4**:359-378.

Rao, K., and C. Geisler. 1990. The social consequences of protected areas development for resident populations Society and Natural Resources **3**:19-32.

Ravenel, R. M., and K. H. Redford. 2005. Understanding IUCN Protected Area categories. Natural Areas Journal **25**:381-389.

Ray, A., and S. Ray. 2007. Chilika Lease Policy-Threat to Environment and Fishermen in P. K. Mohanty, editor. Lakes and Coastal Wetlands: Conservation, Restoration and Management. Capital Publishing Company, New Delhi.

Reason, P., and H. Bradbury 2008. The SAGE handbook of action research: Participative inquiry and practice. Sage Publications, UK.

Redford, K. H., and S. E. Sanderson. 2000. Extracting Humans from Nature. Conservation Biology **14**:1362-1364.

Redpath, S. M., B. E. Arroyo., F. M. Leckie., P. Bacon., N. Bayfield., R. J. GutiÉRrez., and S. J. Thirgood. 2004. Using Decision Modeling with Stakeholders to Reduce Human & Wildlife Conflict: a Raptor & Grouse Case Study. Conservation Biology **18**:350-359.

Reeves, R. R., Jefferson, T.A., Karczmarski, L., Laidre, K., O'Corry-Crowe, G., Rojas-Bracho, L., Secchi, E.R., Slooten, E., Smith, B.D., Wang, J.Y. & Zhou, K. 2008. *Orcaella heinsohni*. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 04 March 2009.

Regan, H. M., M. Colyvan, and M. A. Burgman. 2000. A proposal for fuzzy International Union for the Conservation of Nature (IUCN) categories and criteria. Biological Conservation **92**:101-108.

Regan, H. M., M. Colyvan, and M. A. Burgman. 2002. A Taxonomy and Treatment of Uncertainty for Ecology and Conservation Biology. Ecological Applications **12**:618-628.

Regan, H. M., H. R. Akcakaya, S. Ferson, K. V. Root, S. Carrol, and L. R. Ginzburg. 2003. Treatment of uncertainty and variability in ecological risk assessment of single-species populations. Human and Ecological Risk Assessment **9**:889.

Reiczigel, J., Z. Lang, L. Rózsa, and B. Tóthmérész. 2008. Measures of sociality: two different views of group size. Animal Behaviour **75**:715-721.

Rexstad, E. and K.P. Burnham 1991. User's guide for interactive program CAPTURE: Abundance estimation of closed animal populations. Page 30. Colorado State University, Fort Collins, USA, Fort Collins.

Reynolds JE III, Perrin WF, Reeves RR, Montgomery S, Ragen TJ (eds) (2005) Marine mammal research: conservation beyond crisis. Johns Hopkins University Press, Baltimore, Maryland

Rice, D. W. 1998. Marine Mammals of the World. Systematics and Distribution. Society for Marine Mammology. Special Publication 4: 231pages

Riley, S. J., D. J. Decker, L. H. Carpenter, J. F. Organ, W. F. Siemer, G. F. Mattfeld, and G. Parsons. 2002. The Essence of Wildlife Management. Wildlife Society Bulletin **30**:585-593.

Rodríguez-Martínez, R. E. 2008. Community involvement in marine protected areas: The case of Puerto Morelos reef, México. Journal of Environmental Management **88**:1151-1160.

Rudman, R. 1998. The social organisation of feral donkeys (*Equus asinus*) on a small Caribbean island (St. John, US Virgin Islands). Applied Animal Behaviour Science **60**:211-228.

Salafsky, N., and R. Margoluis. 1999. The Threat Reduction Assessment (TRA) approach to measuring conservation success: a practical and cost-effective framework for evaluating conservation and development projects. Conservation Biology **13**:830-841.

Salafsky, N. and E. Wollenberg. 2000. Linking Livelihoods and Conservation: A Conceptual Framework and Scale for Assessing the Integration of Human Needs and Biodiversity World Development **28**:1421-1438.

Salafsky, N., H. Cauley, G. Balachander, B. Cordes, C. J. Parks, S. Margoluis, C. Bhatt, D. Encarnacion, and R. R. Margoluis. 2001. A Systematic Test of an Enterprise Strategy for Community-Based Biodiversity Conservation. Conservation Biology **15**:1585-1595.

Salafsky, N., R. Margoluis, K. H. Redford, and J. G. Robinson. 2002. Improving the Practice of Conservation: a Conceptual Framework and Research Agenda for Conservation Science. Conservation Biology **16**:1469-1479.

Salafsky, N., D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H. M. Butchart, B. Collen, N. Cox, L. L. Master, S. O'Connor, and D. Wilkie. 2008. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions. Conservation Biology **22**:897-911.

Samuels, A., and L. Bejder. 2004. Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida, USA. Journal of Cetacean Research & Management **6**:69-77.

Sarma, K. V. L. N. S., M. V. Ramana, V. Subramanyam, K. S. Krishna, T. Ramprasad, and, and M. Desa. 2000. Morphological features in the Bay of Bengal. Journal of Indian Geophysics **4**:185-190.

Sathasivam, K. 2002. A Catalogue of Marine Mammal Records, Madurai, India.

Sayer, J. 1991. Rainforest buffer zones: guidelines for protected area managers. Gland, Switzerland: IUCN.

Schipper, J., J. S. Chanson, F. Chiozza, N. A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A. S. L. Rodrigues, S. N. Stuart, H. J. Temple, J. Baillie, L. Boitani, T. E. Lacher, Jr., R. A. Mittermeier, A. T. Smith, D. Absolon, J. M. Aguiar, G. Amori, N. Bakkour, R. Baldi, R. J. Berridge, J. Bielby, P. A. Black, J. J. Blanc, T. M. Brooks, J. A. Burton, T. M. Butynski, G. Catullo, R. Chapman, Z. Cokeliss, B. Collen, J. Conroy, J. G. Cooke, G. A. B. da Fonseca, A. E. Derocher, H. T. Dublin, J. W. Duckworth, L. Emmons, R. H. Emslie, M. Festa-Bianchet, M. Foster, S. Foster, D. L. Garshelis, C. Gates, M. Gimenez-Dixon, S. Gonzalez, J. F. Gonzalez-Maya, T. C. Good, G. Hammerson, P. S. Hammond, D. Happold, M. Happold, J. Hare, R. B. Harris, C. E. Hawkins, M. Haywood, L. R. Heaney, S. Hedges, K. M.

Helgen, C. Hilton-Taylor, S. A. Hussain, N. Ishii, T. A. Jefferson, R. K. B. Jenkins, C. H. Johnston, M. Keith, J. Kingdon, D. H. Knox, K. M. Kovacs, P. Langhammer, K. Leus, R. Lewison, G. Lichtenstein, L. F. Lowry, Z. Macavoy, G. M. Mace, D. P. Mallon, M. Masi, M. W. McKnight, R. A. Medellin, P. Medici, G. Mills, P. D. Moehlman, S. Molur, A. Mora, K. Nowell, J. F. Oates, W. Olech, W. R. L. Oliver, M. Oprea, B. D. Patterson, W. F. Perrin, B. A. Polidoro, C. Pollock, A. Powel, Y. Protas, P. Racey, J. Ragle, P. Ramani, G. Rathbun, R. R. Reeves, S. B. Reilly, J. E. Reynolds, III, C. Rondinini, R. G. Rosell-Ambal, M. Rulli, A. B. Rylands, S. Savini, C. J. Schank, W. Sechrest, C. Self-Sullivan, A. Shoemaker, C. Sillero-Zubiri, N. De Silva, D. E. Smith, C. Srinivasulu, P. J. Stephenson, N. van Strien, B. K. Talukdar, B. L. Taylor, R. Timmins, D. G. Tirira, M. F. Tognelli, K. Tsytsulina, L. M. Veiga, J.-C. Vie, E. A. Williamson, S. A. Wyatt, Y. Xie, and B. E. Young. 2008. The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. Science **322**:225-230.

Schusler, T. M., D. J. Decker, and M. J. Pfeffer. 2003. Social Learning for Collaborative Natural Resource Management. Society and Natural Resources **15**:309–326.

Sekhar, N.U. 2003. Local people's attitudes towards conservation and wildlife tourism around Sariska Tiger Reserve, India. Journal of Environmental Management **69**:339-347.

Sekhar, N. U. 2004. Fisheries in Chilika lake: how community access and control impacts their management. Journal of Environmental Management **73**:257-266.

Sekhar, N. U. 2007. Social Capital and Fisheries Management: The Case of Chilika Lake in India. Environmental Management **39**:497-505.

Sekhsaria, P. 2005. The Dhamra Port in Orissa. Indian Ocean Turtle Newsletter **1**:1-16.

Shaffer, M. L. 1990. Population viability analysis. Conservation Biology **4**:39-40.

Shanker, K. 2004. Marine turtle status and conservation in the Indian Ocean. Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context. FAO Fisheries Report. No. 738, Suppl. 238p. FAO, Rome.

Shanker, K., A. Hiremath, and K. Bawa. 2005. Linking Biodiversity Conservation and Livelihoods in India. PLoS Biol **3** 1878-1880.

Shier, D. M., and J. A. Randall. 2004. Spacing as a predictor of social organisation in Kangaroo rats *(Dipodomys heermanni arenae)*. Journal of Mammalogy **85**:1002-1008.

Sinha, R. K. 2004. The Irrawaddy dolphin (*Orcaella brevirostris*) of Chilika Lagoon, India Journal Bombay Natural History Society **101**:244-251.

Slooten, E., S. M. Dawson, and H. Whitehead. 1993. Associations among photographically identified Hector's dolphins. Canadian Journal of Zoology. 71(11). 1993. 2311-2318.

Smith, A. J., and H. Marsh. 1990. Management of traditional hunting of dugongs [*Dugong dugon* (Muller, 1776)] in the Northern Great Barrier Reef, Australia. Environmental Management **14**:47-55.

Smith, B. D., and L. Hobbs. 1997. A conservation plan for dolphins in the Ayeyarwady River. Pages 1-12. Aquatic Biodiversity Associates, Arcata.

Smith, B. D., and Jefferson, T.A. 2002. Status and conservation of Facultative Freshwater cetaceans in Asia in T. Jefferson, A., and B. D. Smith, editors. Facultative

Freshwater Cetaceans of Asia: Their Ecology and Conservation. The Raffles Bulletin of Zoology. Supplement No. 10
Smith, B. D., and L. Hobbs. 2002. Status of Irrawaddy dolphins *Orcaella brevirostris* in the upper reaches of the Ayeyarwady River, Myanmar. Pages 67-74 in T. Jefferson, A., and B. D. Smith, editors. Facultative Freshwater Cetaceans of Asia: Their Ecology and Conservation. The Raffles Bulletin of Zoology. Supplement No. 10.
Smith, B.D, I. Beasley, M. Buccat, V. Calderon, R. Evina, J. Lemmuel de Valle, A. Cadigal, E. Tura, and Z. Visitacion. 2004. Status, ecology and consrvation of Irrawaddy dolphins *Orcaella brevirostris* in Malampaya Sound, Palawan, Philippines. Journal of cetacean research and management **6**:41-52.
Smith, B. D., B. Ahmed, R. Mansur, A. Mya Than Tun, and T. Tun. 2005. New information on the status of finless porpoises *Neophocaena phocaenoides* and Irrawaddy dolphins *Orcaella brevirostris* in Bangladesh and Myanmar. International Whaling Commission. Working Paper Series. Small Mammal Group **SC/57/SM4**:1-19.
Smith, B. D., G. Braulik, S. Strindberg, B. Ahmed, and R. Munsur. 2006. Abundance of Irrawaddy dolphins (*Orcaella brevisrostris*) and Ganges River dolphins (*Platanista gangetica gangetica*) estimated using concurrent counts made by independent teams in waterways of the Sundarbans mangrove forest in Bangladesh. Marine Mammal Science **22**:527-547.
Smith, B. D., and Tun, M.T. 2007a. Review of the Status and Conservation of Irrawaddy Dolphins *Orcaella brevirostris* in the Ayeyarwady River of Myanmar. Pages 21-40 in B. D. Smith, Shore R. G and Lopez, A, editor. Status and conservation of Freshwater populations of Irrawaddy dolphins WCS, Pnom Penh.
Smith, B. D., Shore, R.G., Lopez, A., Beasley, I. Gilbert, M., Sokha, K. Kittawattanawong, K. Kreb, D. Moelyono, H., Tun, M.T., Channy, O., Pattnaik, A.K., Phay, S., Phothitay, C., Sutaria, D., and Tint, T. 2007b. Action Plan for the Conservation of Freshwater Populations of Irrawaddy Dolphins in R. G. Shore. B.D. Smith, A. Lopez, editor. In Status and Conservation of Freshwater Populations of Irrawaddy Dolphins. Wildlife Conservation Society Pnom Penh.
Smolker, R. A., A. F. Richards, R. C. Connor, and J. W. Pepper. 1992. Sex Differences in Patterns of Association among Indian Ocean Bottlenose Dolphins. Behaviour **123**:38-69.
Sodhi, N. S., and Liow, L.H. 1999. Improving conservation biology research in Southeast Asia. Conservation Biology **14**:1211-1212.
Stacey, P., and S. Leatherwood. 1997. The Irrawaddy dolphin, *Orcaella brevirostris*: A summary of current knowledge and recommendations for conservation action. Asian Marine Biology **14**:195-214.
Stacey, P. J., and P. W. Arnold. 1999. Orcaella brevirostris. Mammalian Species **616**:1-8.
Sukumar, R. 2006. A brief review of the status, distribution and biology of wild Asian elephants *Elephas maximus*. International Zoo Yearbook **40**:1-8.
Sutaria, D., and, and T. Jefferson. 2004. Records of Indo-Pacific Humpback Dolphins (*Sousa chinensis*, Osbeck, 1765) Along the Coasts of India and Sri Lanka: An Overview. Aquatic Mammals **30** 125-136.
Sutherland, W. J., A. S. Pullin, P. M. Dolman, and T. M. Knight. 2004. The need for evidence-based conservation. Trends in Ecology & Evolution **19**:305-308.

Tao, T. C. H., and G. Wall. 2009. Tourism as a sustainable livelihood strategy. Tourism Management **30**:90-98.

Taylor, B., S. J. Chivers, J. A. Larese, and W. F. Perrin. 2007a. Generation length and percent mature estimates for IUCN assessments of cetaceans. Southwest Fisheries Science Center, La Jolla, San Diego.

Taylor, B. L., M. Martinez, T. Gerrodette, J. Barlow, and Y. N. Hrovat. 2007b. Lessons from monitoring trends in abundance of marine mammals. Marine Mammal Science **23**:157-175.

Thiele, D. 2005. Report of an opportunistic survey for Irrawaddy dolphins, *Orcaella brevirostris*, off the Kimberley coast, northwest Australia. Working paper presented at the 57th International Whaling Commission annual meeting, Small Cetaceans Scientific Committee (IWC/SC57/SM2), Ulsan, Republic of Korea.

Thompson, P. M., B. Wilson, K. Grellier, and P. S. Hammond. 2000. Combining power analysis and population viability analysis to compare traditional and precautionary approaches to conservation of coastal cetaceans. Conservation Biology **14**:1253-1263.

Tripathi, S., and, and K. H. Vora. 2005. Maritime heritage in and around Chilika Lake, Orissa:Geological evidences for its decline. Current Science **88**:1175-1181.

Tripathy, B., and B. C. Choudhury. 2004. Occurrence and mortality of marine mammals along the Andhra Pradesh coast, East coast of India. Indian Forester **130**:1132-1140.

Tun, T. 2003. Current status of Ayeyawady (Irrawaddy) dolphin in the Ayeyawady river, Myanmar. Page 16. WCS, Yangon.

Van Waerebeek, K., A. N. Baker, F. Felix, J. Gedamke, M. Iniguez, G. P. Sanino, E. Secchi, D. Sutaria, A. Van Helden, and Y. Wang. 2007. Vessel collisions with small cetaceans worldwide and with large whales in the southern hemisphere, an initial assessment Latin American Journal of Aquatic Mammals **6**:43-69.

Wade, P. R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science **14**:1-37.

Wells, M., and K. Brandon 1992. People and Parks: Linking Protected Areas with Local Communities. World Bank, Washington, DC, USA.

Wells, R. S. 2003. Dolphin Social Complexity. Page 616 pages in B. M. F. Waal, and P. Tyack, editors. Animal Social Complexity: Intelligence, Culture, and Individualized Societies. Harvard University Press, Boston.

Western, D., M. Wright, and S. Strumm 1994. Natural Connections: Perspectives in Community-based Conservation. Island Press, Washington, DC, USA.

White, G. C. 2007. Program Mark 4.3. http://www.cnr.colostate.edu/~gwhite/mark/mark.htm. Department of Fishery and Wildlife, Colorado State University, Fort Collins- 80523, Colorado.

White, P. C. L., N. V. Jennings, A. R. Renwick, and N. H. L. Barker. 2005. Questionnaires in ecology: a review of past use and recommendations for best practice. Journal of Applied Ecology **42**:421-430.

Whitehead, H., S. Brennan, and D. Grover. 1992. Distribution and Behaviour of Male Sperm Whales on the Scotian Shelf Canada. Canadian Journal of Zoology **70**:912-918.

Whitehead, H., and S. Dufault. 2001. Techniques for analyzing vertebrate social structure using identified individuals: review and recommendations. Advances in the Study of Behavior **28**:33-74.

Whitehead, H. 2008. SOCPROG 2.3.

Whyte, W. F. 1989. Advancing scientific knowledge through participatory action research. Sociological Forum **4**:367-385.

Williams, B. K., Nichols J.D., and Conroy, M.J. 2002. Analysis and management of animal populations. Academic Press, San Diego, California, USA.

Williams, J. A., S. M. Dawson, and E. Slooten. 1993. The abundance and distribution of bottlenosed dolphins (*Tursiops truncatus*) in Doubtful Sound, New Zealand. Canadian Journal of Zoology **71**.

Wilshusen, P. R., S. R. Brechin, C. L. Fortwangler, and P. C. West. 2002 Reinventing a square wheel: Critique of a resurgent "Protection Paradigm" in international biodiversity conservation. Society and Natural Resources **15**:17-40.

Wilson, B., P. S. Hammond, and P. Thompson. 1999. Estimating Size and Assessing Trends in a Coastal Bottlenose Dolphin Population. Ecological Applications **9**:288-300.

Worton, B. J. 1989. Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies. Ecology **70**:164-168.

Wrangham, R. W. 1980. An ecological model of female-bonded primate groups. Behaviour **75**:262-300.

Wrangham, R. W. 1987. Evolution of social structure. Primate Societies:282-296.

Wrangham, R. W., J. L. Gittleman, and C. A. Chapman. 1993 Constraints on group size in primates and carnivores: population density and day-range as assays of exploitation competition. Behavioral Ecology and Sociobiology **32**:199-209.

Würsig, B., Wells R.S., and K. S. Norris. 1994. Food and Feeding. Pages 216-231 in K. S. Norris, B. Würsig., R. S. Wells, and M. Würsig, editors. The Hawaiian spinner dolphin. University of California Press, Berkeley.

APPENDIX A: Catalogue of photo-identified dorsal fins of Irrawaddy dolphins in Chilika Lagoon


A1 (seen with calf) FEM


A2 (seen with juvenile) FEM


A3 (seen with calf) FEM


A4


A5 (seen with calf) FEM


A6


A7


A8


A9


A10


A11

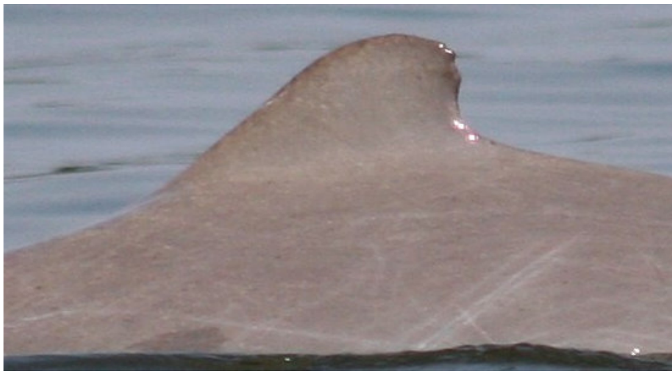

A12


A13

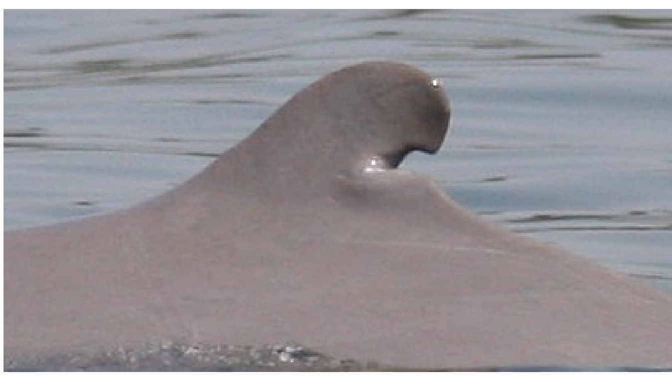

A14


A15


A16


A17


A18 (seen with newborn calf)


A19


A20

A20a

A21

A22

A24 (with juvenile)


A25


A26


A27 (seen with juvenile) FEM


A28

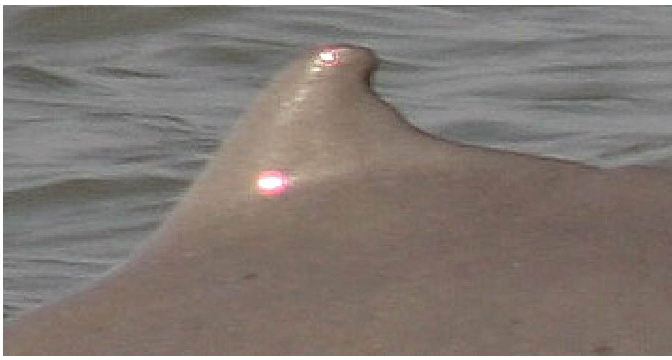

A29 FEM


A30


A31


A32


A33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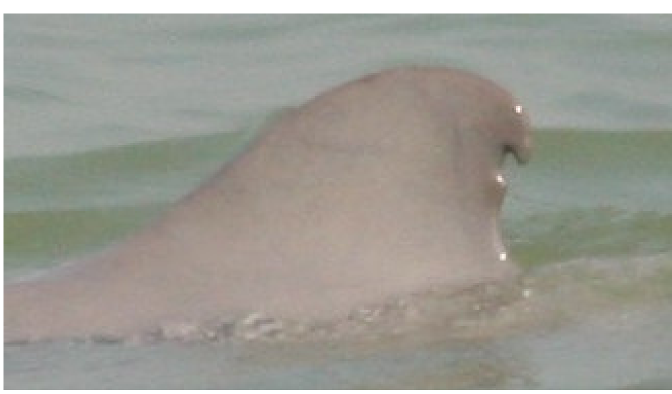
A35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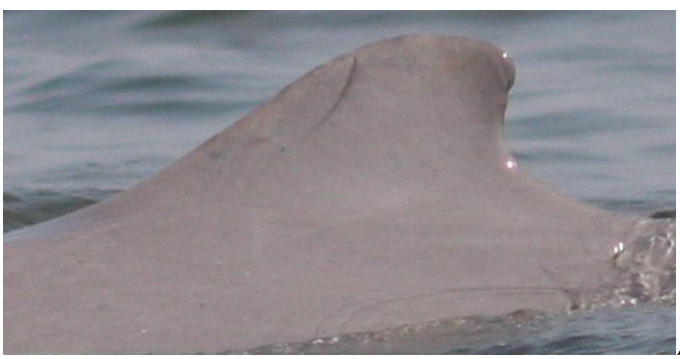
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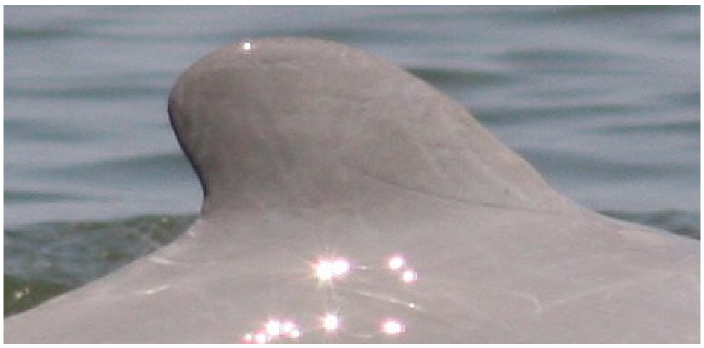
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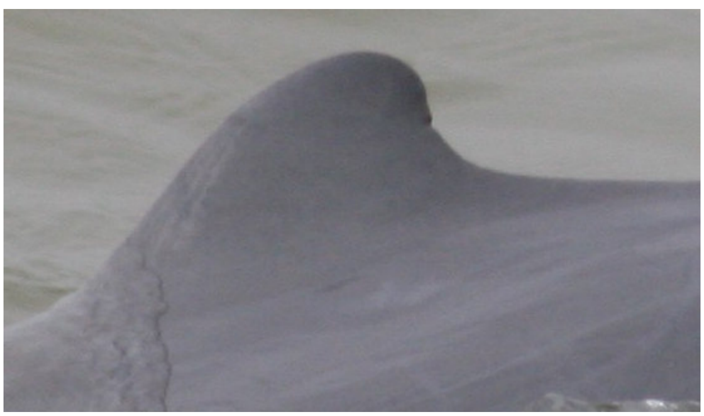
A67


A69 (identified with scar on head)


A71


A72


A73


A74


A75


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A83


A86


A87


A88


A89

APPENDIX B: Feeding and Socializing Behavioral states

Feeding: Various types of feeding behaviors have been documented using still and video photography

Feeding from a stilted fixed trap-sideways feeding seen in solitary and cooperative groups feeding on small sized fish

Feeding from a large mesh size gill net-usually seen in solitary animals


Mud plume feeding, solitary or between two individuals, feeding usually on small sized fish

Feeding on Scat fish – Solitary feeding observation

Feeding on Scoliodon - Cooperative feeding observation

Feeding on Mullet - Cooperative feeding observation

Feeding on Mullet – Solitary feeding observation

Synchronized tail slapping observed in cooperative feeding groups

‘Spitting water’ was observed to scare fish and is part of both cooperative and solitary feeding strategies

Socializing

APPENDIX C: Age classes


New-born calf with adult


Juvenile


Sub-adult


Calf with adults


Adult

APPENDIX D: Fishing gear commonly active in Chilika

Zero mesh nets to catch prawn seed
Monofilament nets: mesh size ranging between 25-30 mm.
Multifilament large meshed gill nets 50-90mm mesh size – the *sankutch/ bhekti jaal*

Large and Medium mesh size multifilament gill nets

Monofilament gill net (Disco Jaal and Dubbi Jaal)

Tremmel Net (Dubbi jaal-mixed mesh size and multilayered net)

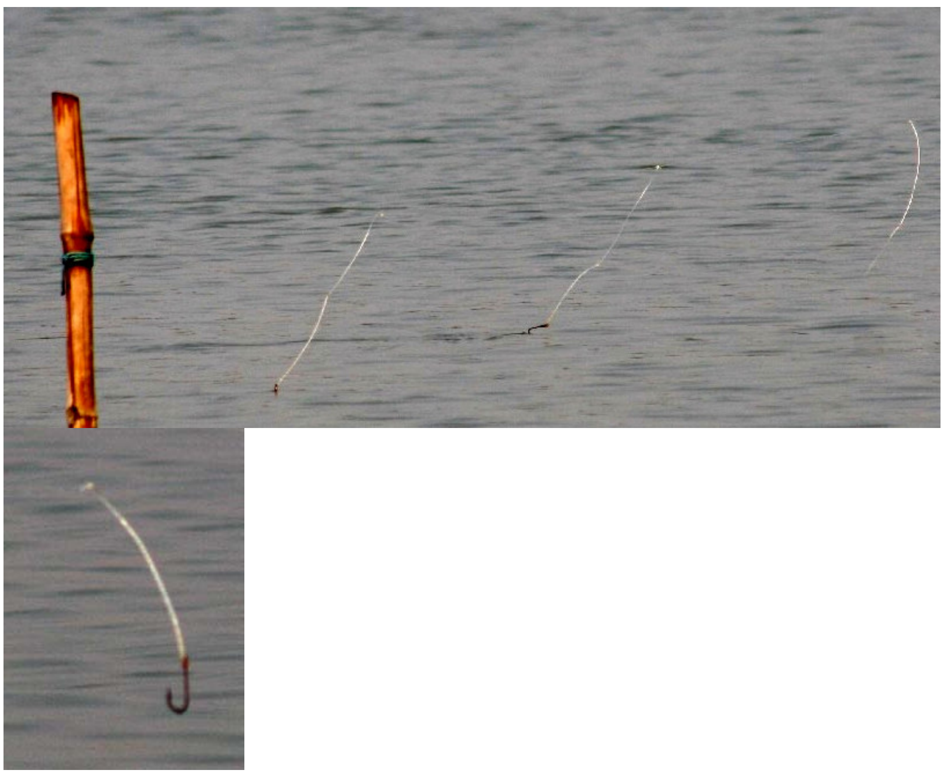
Boat seine net (small mesh size)

Shore seine net (Alimi or Muni Jaal)-lower picture shows the net being pulled to shore.

Cast nets, mainly seen along shores or at the mouth to the sea

Most common and widespread form of fishing: Fixed fish and shrimp traps (Khonda/Pudda Jaal)


Aquaculture enclosure (Gheri)


Hook Line (Kaata Jaal) – South, Central and Outer Channel regions


Rod and Line fishing in the Outer Channel

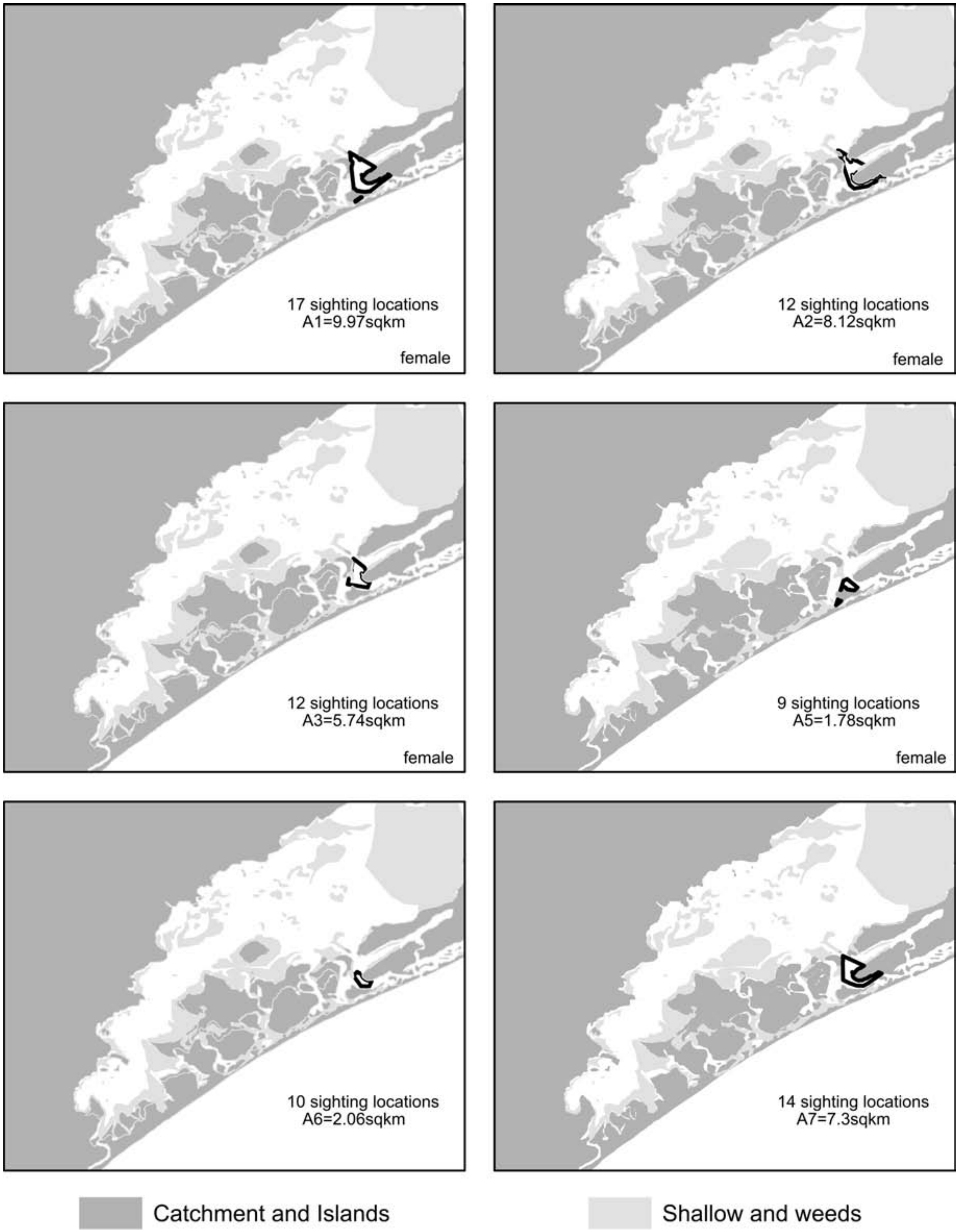
Crab trap (Kakda Jaal)

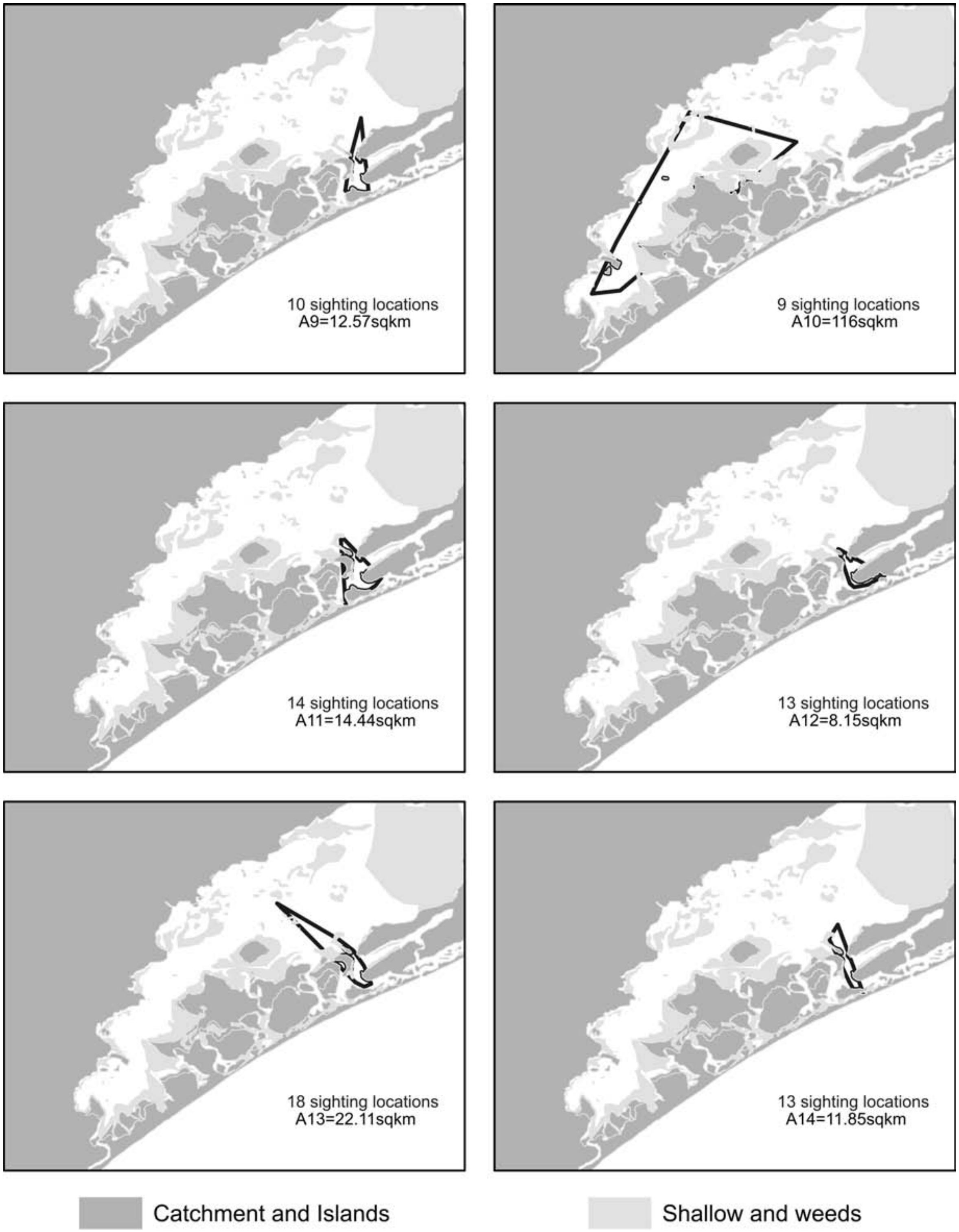
Mollusc, prawn seed collectors

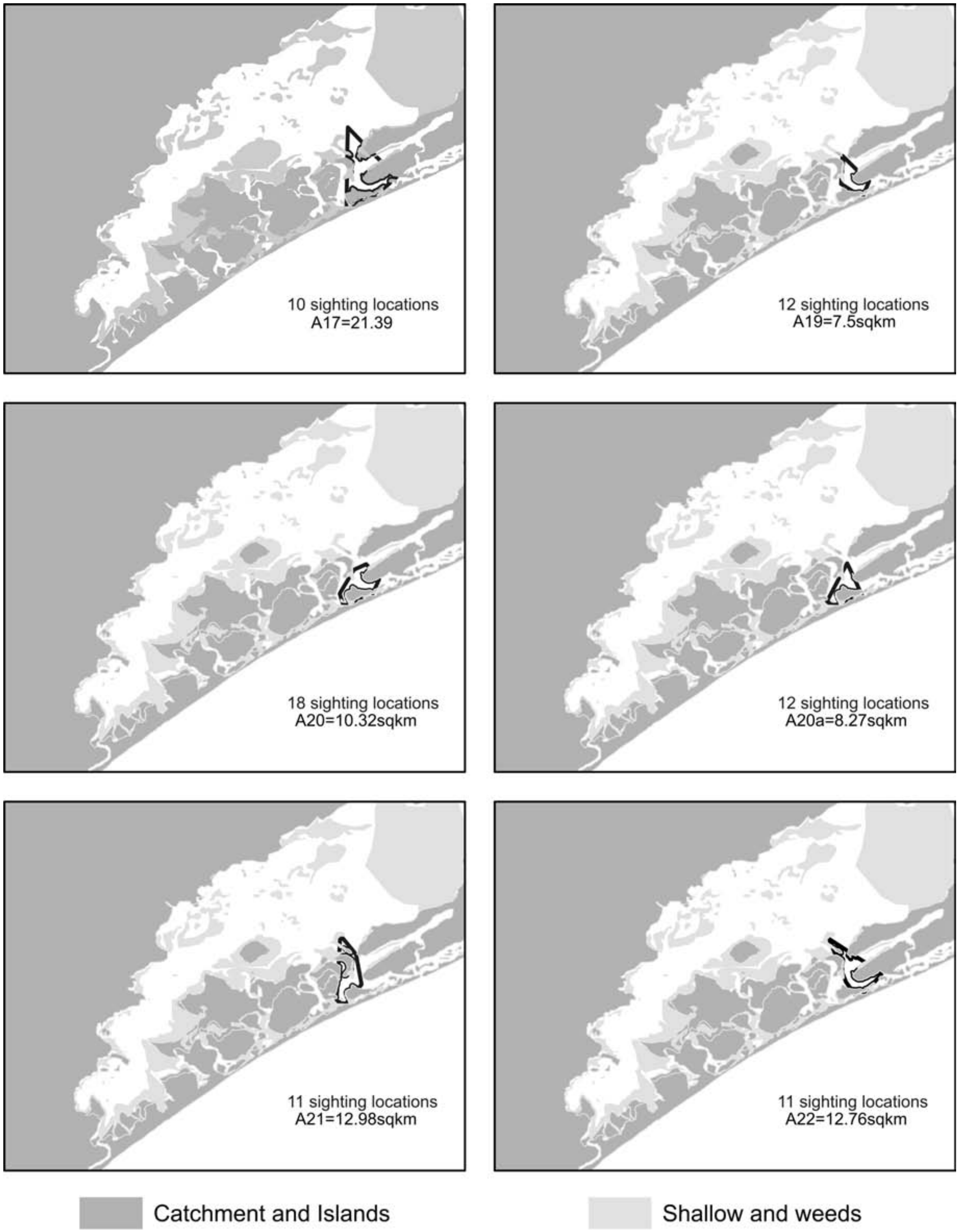
Small traditional seine

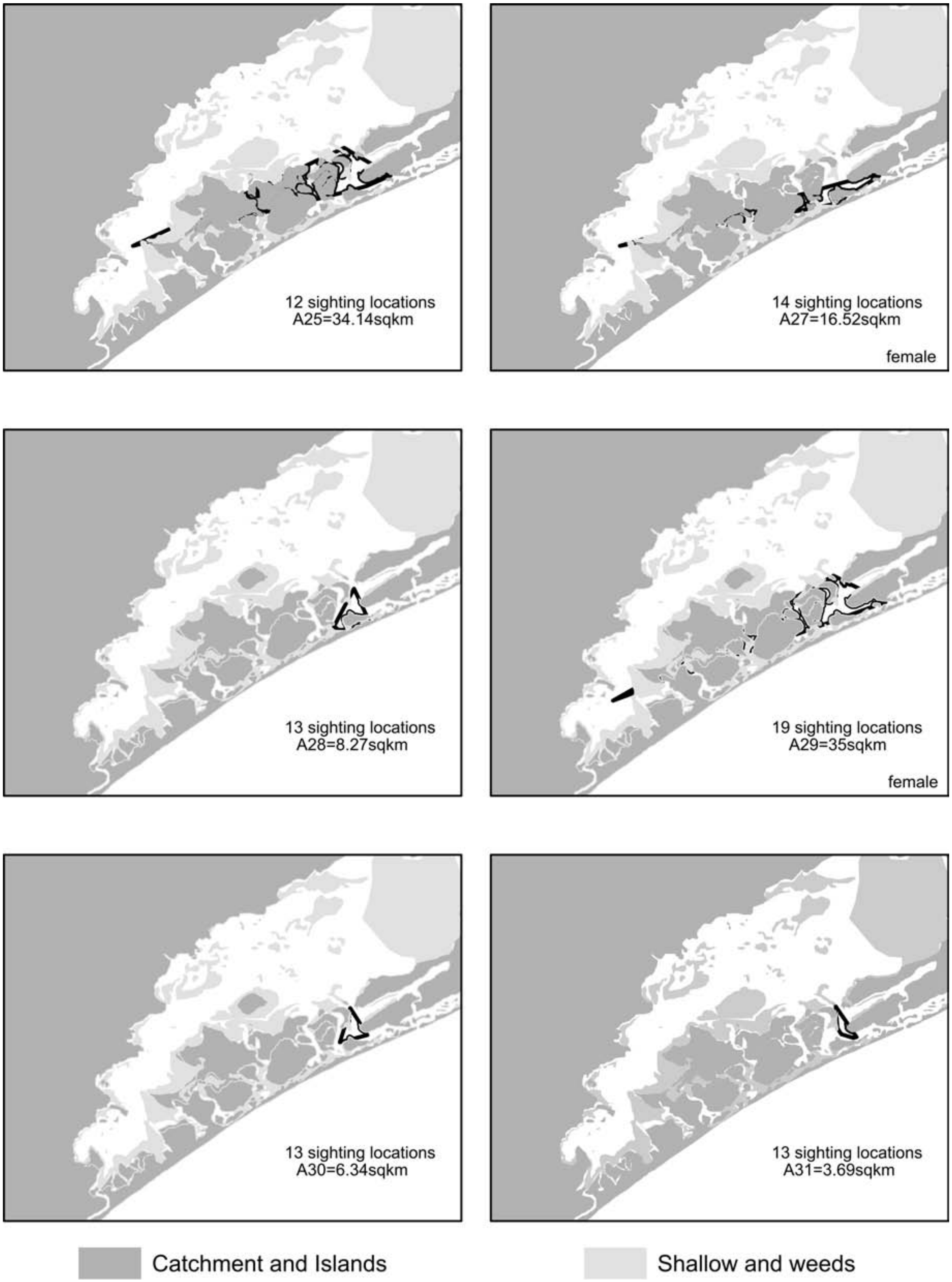
Bag nets on stilts found commonly in the channel leading from the sea mouth to Arakuda.

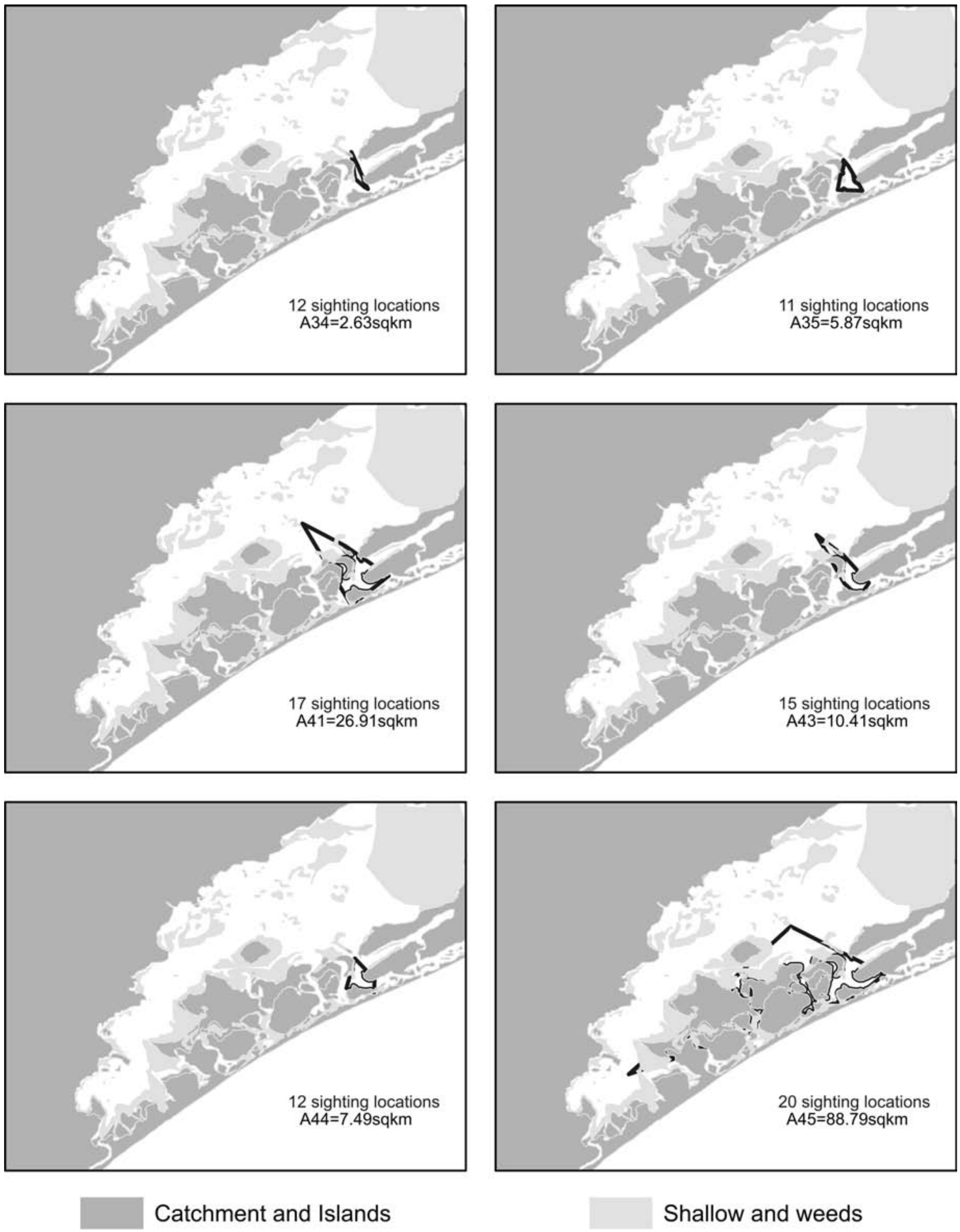
APPENDIX E: Home ranges for individual animals using Minimum Convex Polygons

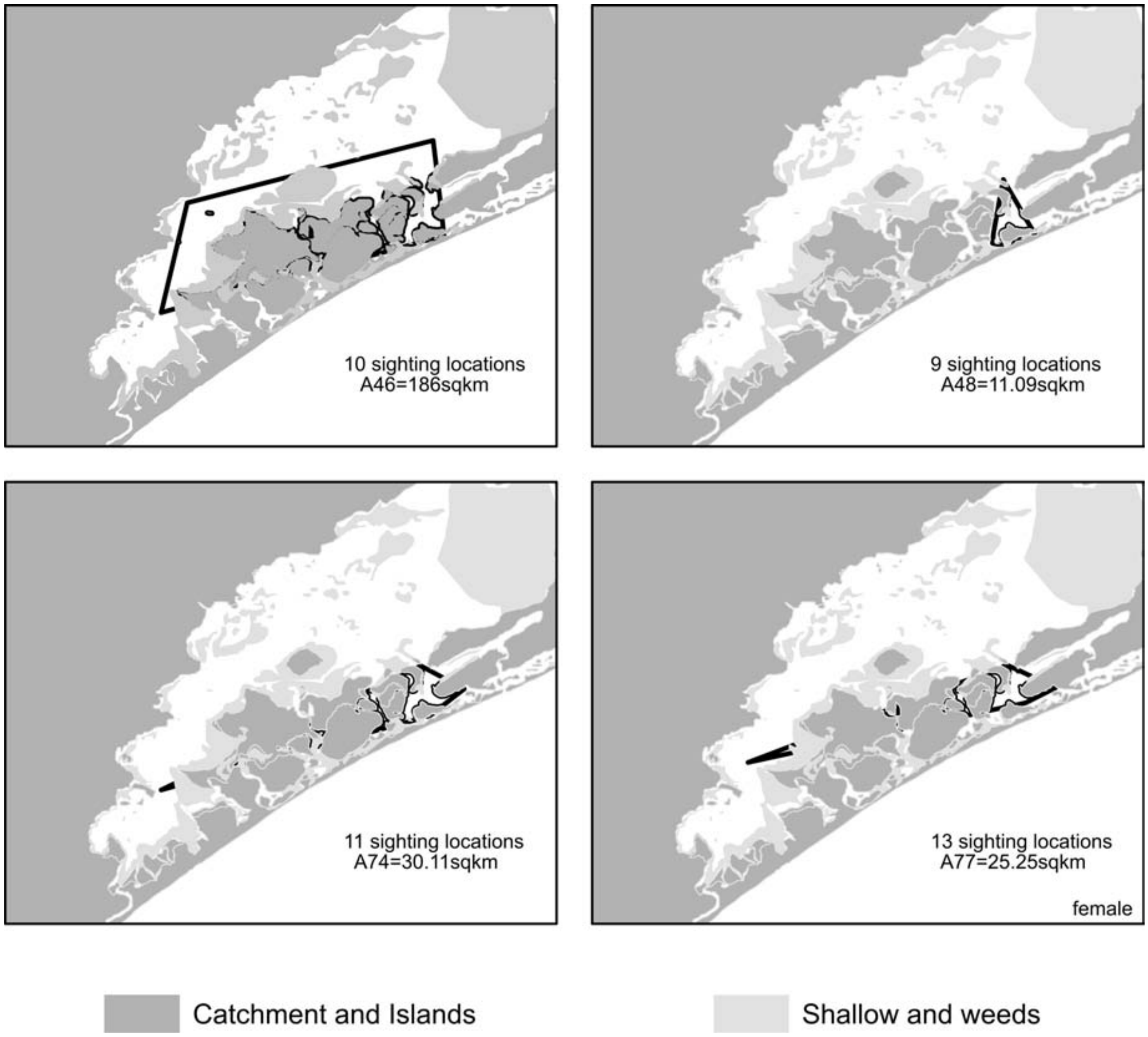


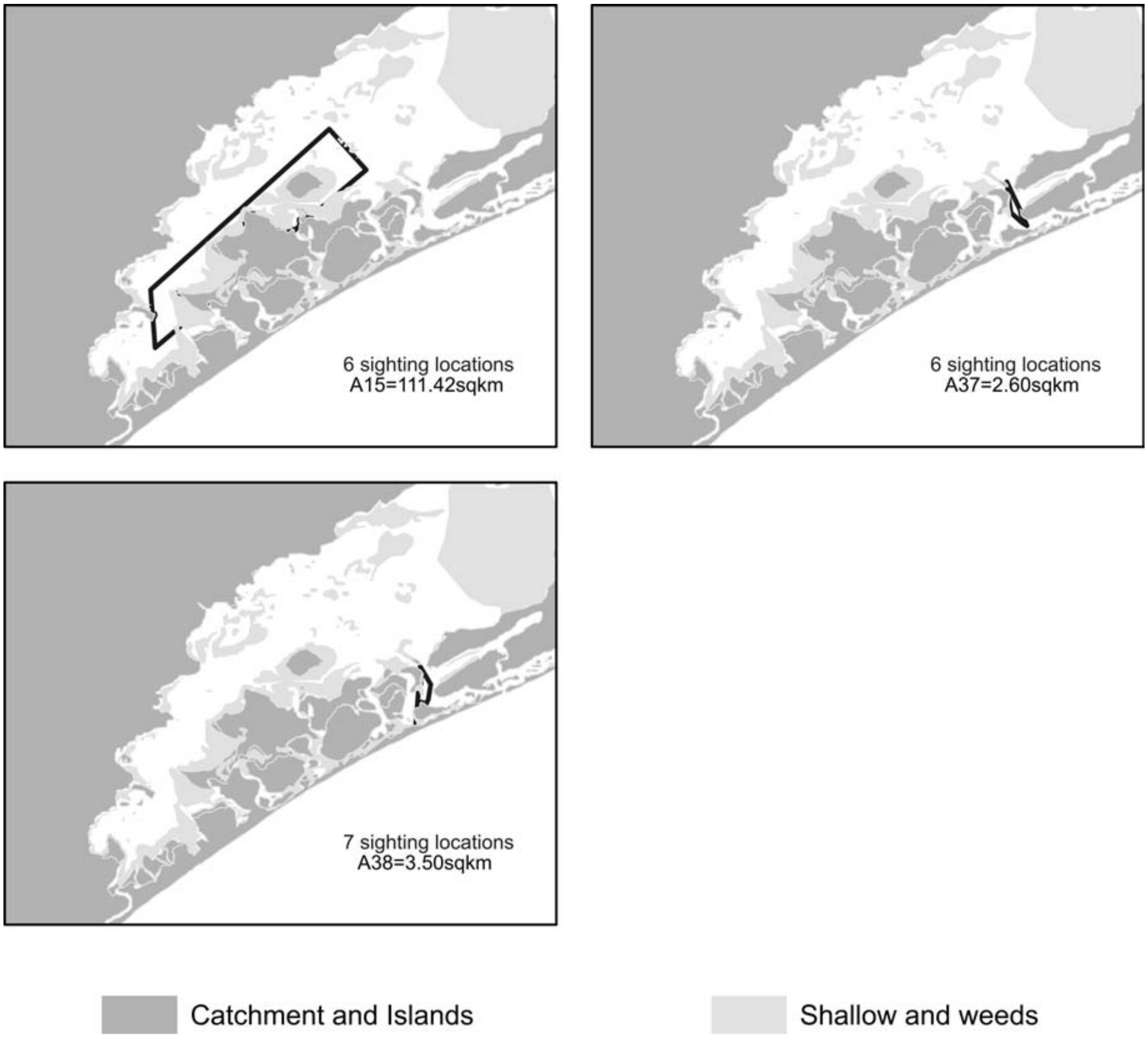

10 sighting locations
A9=12.57sqkm
9 sighting locations
A10=116sqkm
14 sighting locations
A11=14.44sqkm
13 sighting locations
A12=8.15sqkm
18 sighting locations
A13=22.11sqkm
13 sighting locations
A14=11.85sqkm
Catchment and Islands
Shallow and weeds


10 sighting locations
A17=21.39
12 sighting locations
A19=7.5sqkm
18 sighting locations
A20=10.32sqkm
12 sighting locations
A20a=8.27sqkm
11 sighting locations
A21=12.98sqkm
11 sighting locations
A22=12.76sqkm
Catchment and Islands
Shallow and weeds


12 sighting locations
A25=34.14sqkm
14 sighting locations
A27=16.52sqkm
female
13 sighting locations
A28=8.27sqkm
19 sighting locations
A29=35sqkm
female
13 sighting locations
A30=6.34sqkm
13 sighting locations
A31=3.69sqkm
Catchment and Islands
Shallow and weeds


12 sighting locations
A34=2.63sqkm
11 sighting locations
A35=5.87sqkm
17 sighting locations
A41=26.91sqkm
15 sighting locations
A43=10.41sqkm
12 sighting locations
A44=7.49sqkm
20 sighting locations
A45=88.79sqkm
Catchment and Islands
Shallow and weeds


10 sighting locations
A46=186sqkm
9 sighting locations
A48=11.09sqkm
11 sighting locations
A74=30.11sqkm
13 sighting locations
A77=25.25sqkm
female
Catchment and Islands
Shallow and weeds

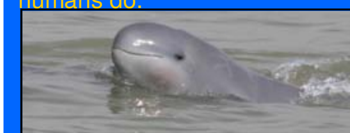

6 sighting locations
A15=111.42sqkm
6 sighting locations
A37=2.60sqkm
7 sighting locations
A38=3.50sqkm
Catchment and Islands
Shallow and weeds

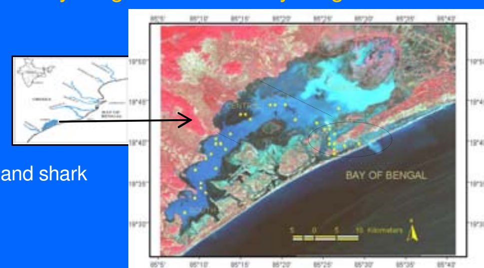
APPENDIX F: Communication material produced during the study period

1. Posters for tourists distributed to local restaurants at Chilika, tourist boat associations at Chilika and hotels in Puri and Bhubaneswar.

WELCOME TO CHILIKA

Indian waters have 30 species of cetaceans (whales, dolphins and porpoises)!!! Dolphins and whales are MAMMALS and not fish. They give birth to live young and milk their young ones like humans do.





"We are scared of boat traffic, hook line fisheries and large seine and shark nets, protect us from them and we will make you smile"

UNIQUE to Chilika- Irrawaddy Dolphin (*Orcaella brevirostris*)

Chilika is home to 132 villages and more than 2lakh fishermen. The **dolphin and the traditional fisherman** have lived together peacefully for more than a 100 years. Sadly, more than 50 animals have died between 2000-2005 and the population is prone to extinction.

Species Information: Scattered populations from east coast of India till the North east coast of Philippines and Indonesia.
The dolphins in Chilika are residential and do not go out of the lagoon. 75-85 Irrawaddy dolphins presently survive in Chilika
Adult size: 2-2.75m, Colour: Slate gray with a light coloured belly, Small fin and blunt beak
Dolphins breathe air and give birth to live young once in 3 years. In Chilika new born calves have been seen from June till December.
Dolphins form social groups and communicate with each other like humans do.
Dolphins can be studied by identifying each individual by its dorsal fin. Will you see Hookfin or Scoopfin?.Only if you are lucky and do not disturb a group…………
Like in Chilika, worldwide dolphins are dying due to unsustainable fisheries, detrimental nets, boat traffic and pollution

Hookfin

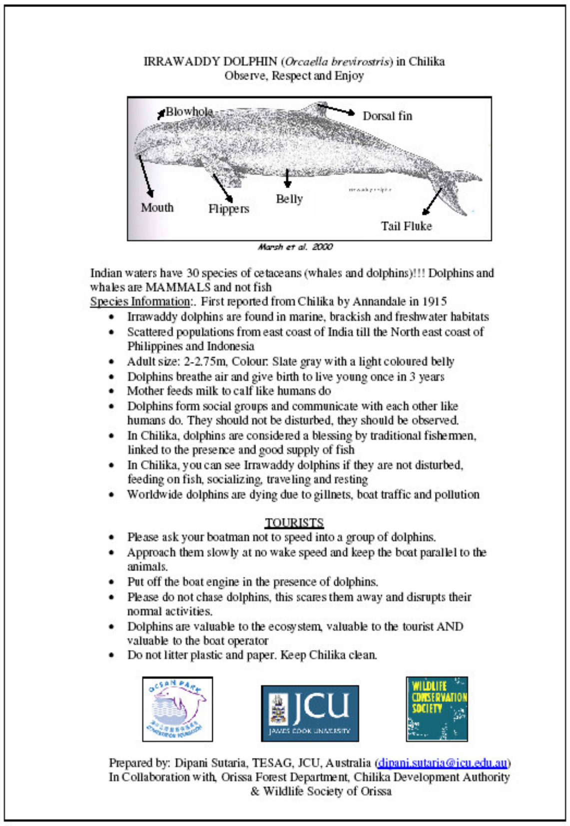
Scoop fin

TOURISTS!!!!!! Please make your trip special….

Approach dolphins slowly at no wake speed and keep the boat parallel to the animals.
Put off the boat engine in the presence of dolphins and do not ask the boat driver chase them, this scares them.
Dolphins are valuable to the ecosystem, valuable to the tourist AND valuable to the boat operator.
PLEASE help the local community to make Chilika a special TOURIST destination. Try to avoid plastic cups and packaged food. Enjoy locally prepared food. Keep Chilika clean.

Research team from JCU with assistants from local villages(dipani.sutaria@jcu.edu.au)

2. Laminated information sheets (n=350) provided to tourist boat associations one for each boat. They were two sided for English and Oriya readers.



IRRAWADDY DOLPHIN (*Orcaella brevirostris*) in Chilika
Observe, Respect and Enjoy

Marsh et al. 2000

Indian waters have 30 species of cetaceans (whales and dolphins)!!! Dolphins and whales are MAMMALS and not fish

Species Information:. First reported from Chilika by Annandale in 1915

- Irrawaddy dolphins are found in marine, brackish and freshwater habitats
- Scattered populations from east coast of India till the North east coast of Philippines and Indonesia
- Adult size: 2-2.75m, Colour: Slate gray with a light coloured belly
- Dolphins breathe air and give birth to live young once in 3 years
- Mother feeds milk to calf like humans do
- Dolphins form social groups and communicate with each other like humans do. They should not be disturbed, they should be observed.
- In Chilika, dolphins are considered a blessing by traditional fishermen, linked to the presence and good supply of fish
- In Chilika, you can see Irrawaddy dolphins if they are not disturbed, feeding on fish, socializing, traveling and resting
- Worldwide dolphins are dying due to gillnets, boat traffic and pollution

TOURISTS

- Please ask your boatman not to speed into a group of dolphins.
- Approach them slowly at no wake speed and keep the boat parallel to the animals.
- Put off the boat engine in the presence of dolphins.
- Please do not chase dolphins, this scares them away and disrupts their normal activities.
- Dolphins are valuable to the ecosystem, valuable to the tourist AND valuable to the boat operator
- Do not litter plastic and paper. Keep Chilika clean.

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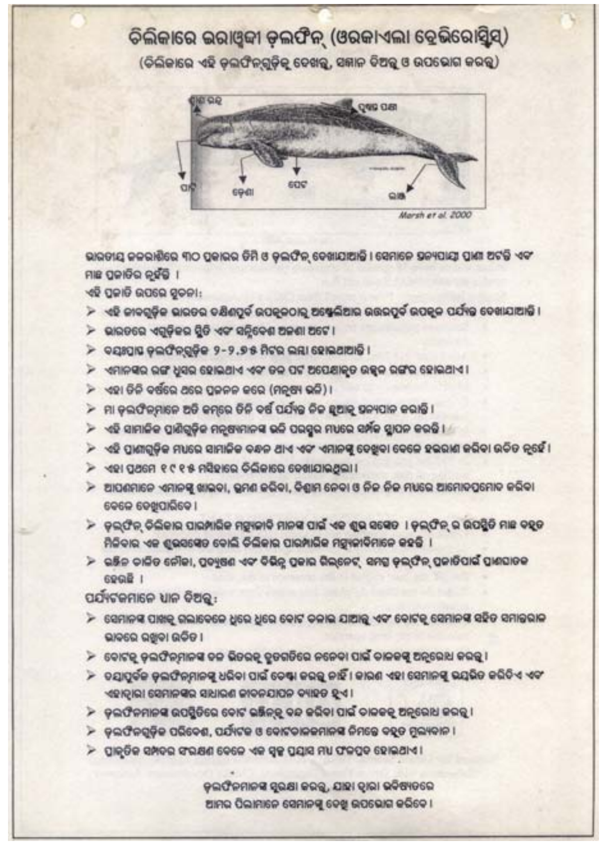
In Collaboration with, Orissa Forest Department, Chilika Development Authority & Wildlife Society of Orissa



3. Brochures expressing the idea of sustainable fisheries in Chilika Lagoon, distributed in all the villages of the Outer Channel.