The spatial behaviour of artisanal fishers: Implications for fisheries management and development (Fishers in Space)

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Executive summary

The ways that fishers distribute their fishing effort over a fishing ground can affect the ecological impacts on and the economic performance of fisheries. This distribution can be influenced by a number of social, economic, and institutional factors such as technology, management, and fishers' knowledge. Many fisheries development and management interventions invariably alter the spatial distribution of fishing effort. Success of interventions such as protected areas and attempts to encourage fishing effort to move offshore often rest on largely untested assumptions about fishers' spatial behaviour, and their willingness or ability to change it. Thus, understanding spatial distribution of fishing effort is increasingly recognised as an important consideration for fisheries management. However, the spatial behaviour of fishers is poorly understood, especially in artisanal, developing country fisheries. The vast majority of research into fishers' spatial behaviour has been conducted in large-scale fisheries, which are able to make use of data rich vessel monitoring systems that are frequently installed in many fishing vessels. In developing countries, however, these vessel monitoring systems are not used and little empirical work has been done to explore fishers' spatial behaviour.

This study used a mixed-methods approach to understand the diverse factors influencing artisanal fishers' spatial behaviour and investigate evidence for perceived or realised 'spillover' benefits to fishers of MPAs. A structured survey and a participatory effort mapping and catch monitoring program in Seychelles and Kenya yielded data on spatial behaviour, factors affecting decision-making, and spatial patterns in fisheries adjacent and not adjacent to MPAs. This project accomplished the following objectives:

1. **Review the extent to which the spatial behaviour of fishers have been evaluated**.
2. **Examine the distribution of fishing effort for artisanal fishers in Kenya.**
3. **Explore how fishers chose their fishing sites in Kenya and Seychelles;**
4. **Examine displacement of fishing effort in Kenya and Seychelles**;
5. **Examine evidence for spillover of catch from marine reserves**

These have been organized into seven chapters:

Chapter 1. Literature review: spatial behaviour of artisanal fishers

Most research on fishers' spatial behaviour has been conducted in developed countries with industrialised fisheries. A wide range of factors can affect spatial behaviour and these have implications for the design and social impact of fisheries closures. Technical, economic, social and psychological factors will affect how fishers respond to closures, both in terms of short term displacement from fishing grounds, potential spill over in the longer term.

Chapter 2. Methods

This project utilised a wide range of qualitative and quantitative methods which informed each others' design or analysis. Methods included surveys, including map-based questions, participant observation, GPS tracking, logbook collection, participatory mapping, focus groups and key informant interviews.

Chapter 3. Where do fishers fish?

Results from surveys indicated some element of segregation of effort between handline and trap fishers between the two main islands in Seychelles. In Kenya fishing effort is concentrated within 1000m of the shoreline on fringing reefs, although distance offshore varies seasonally and significantly by vessel type, with sail and engine power allowing access to offshore grounds.

Chapter 4. How do fishers decide where to fish?

A wide range of factors reportedly influence fisher decision making in Seychelles and Kenya, dominated by weather and currents apart from fuel expenses which have come to dominate decisions in Seychelles where outboard engines are the norm. Fishers' recent or past experience is used to choose fishing grounds but they can also learn from one another, either through communication, or direct observation of others' fishing success.

Chapter 5. Displacement of fishing effort

According to the survey, spatial fishing behaviour is generally consistent with a majority of fishers using the same grounds as 10 years previously, However, 33% of interviewed fishers in Seychelles and 60% in Kenya had been displaced from fishing grounds as a result of fisheries closures or land reclamation (Seychelles). This displacement was unequally experienced with fishers in some landing sites, with lower socioeconomic status, and without fishing boats being more affected by displacement. In some cases this has led to further exploration for new grounds. Exploration in Kenya was reported as being driven specifically by low catches.

Chapter 6. Spillover

In both Seychelles and Kenya it was reported that fishers may fish close to the boundaries of fisheries closures, often with the perception of enhanced catches. Fishers also perceived that they could catch fish which had swum out of the closure. However the majority of fishers in both countries did not perceive an overall impact of closures on their catches. Perceptions of the impacts of MPAs on their livelihood varied between locations and were least positive in Kenya near state-owned parks which had limited benefits for the adjacent fishers.

Chapter 7. Project Conclusions and outputs

This project revealed a number of findings relevant to management and future research.

1. *Spatial behaviour of fishers*

Artisanal fishers' spatial behaviour in both Kenya and Seychelles are affected by a wide range of factors, particularly seasonal weather and vessel types. Based on intensive GPS mapping in Kenya Fishers travel to 26% less far during the rough (SE monsoon) season.

There is some segregation between fishers from different areas in both countries, but considerable overlap between neighbouring landing sites and also potential overlap at sea between larger areas, particularly where larger, motorised or sailed vessels allow fishers from distant landing sites to access the same fishing grounds. This will present challenges for fisheries resource management based on local spatial management units such as Beach Management Units.

2. *Fishers experiences with spillover from marine reserves*

Over 90% of fishers felt that they had caught fishes which spilled over from marine reserves. However, 66% of fishers also felt that they were displaced from the reserve. In total, 20% of fishers perceived increased catch from marine reserves, while 22% felt like their catches declined. Importantly, 35% felt that MPAs were negative for their livelihood. This suggests that although fishers are aware of and claim to experience the potential benefits of marine reserves, they generally do not feel that these outweigh the other social and economic costs.

There are under-recognized distributional inequalities in who marine reserves affect. In particular, it is poorer fishers in Kenya that were both displaced from, and also felt like they benefited from marine reserves.

3. Methodological reflections and considerations

This project developed and applied multiple-methods to investigate artisanal fishers' spatial behaviour with limited resources. Integrated surveys, logbooks, GPS monitoring techniques and accompanying databases have been developed and could be used in other contexts or more widely throughout the WIO region. Some of the key lessons learned are the considerable resource implications of consistent and reliable data collection, management, manipulation and analysis. High levels of fisher involvement and buy in and regular contact and feedback, GIS competent staff on the ground and regular plotting of data to highlight any issues are crucial to run this kind of program.

Chapter 1. Literature review

No-take marine protected areas (MPAs) which prohibit extractive activities such as fishing are increasingly recommended with the view to improve fisheries management (Bohnsack 1996; Roberts 1997; Halpern 2003; Pascoe 2006). However, currently the primary role of a MPA is to control the spatial distribution of fishing pressure and thereby protect the integrity of habitats and species within the MPA (Russ 2002; Halpern 2003). In other words, MPA establishment can be considered to be a manipulation of the existing spatial behaviour of fishers. A number of empirical reports, modelling studies and reviews have examined the effects of MPAs on fishers' catch or profitability (McClanahan 2010; Halpern, White et al. 2011). Yet, the critical area of research on how fishers' behaviour changes in response to MPA implementation has received comparatively little attention (Pascoe 2006), in spite of the fact that this may have a profound bearing on the benefits of the closure.

For the majority of cases where fishing effort is not removed, prohibiting access to specific fishing grounds through no-take MPAs results in displacement of fishing effort. Effort redistribution will happen on two timescales which need to be considered when trying to understand displacement effects. There will be immediate effort displacement after the area is closed. But effort will also continue to be reallocated as the dynamics of fish populations and fisher behaviour change and adjust in response to the new regime (Valcic 2009). Therefore, in both the short and long-term, spatial reallocation of effort will have implications for both profitability and for the ecological impacts of fishing in non-closure areas. In the short term the costs and profits associated with fishing activities will undoubtedly alter with MPA implementation. This will be directly related to size and location of the MPA. Depending on the size of the MPA, congestion in remaining open grounds will increase and may result in interference. With fewer fish per vessel, the profitability of individual fishers will decrease in the short term. If fishers are displaced from their usual fishing grounds, they may face increasing uncertainty about the profitability of available sites. Fishers facing a reduced fishing space and without appropriate provisions in place to address displaced effort, there may be substantial opposition to MPAs, challenging them by legal or illegal means such as poaching. In the long term, MPAs may result in enhanced recruitment and spillover effects which may increase the profitability of adjacent fisheries by changing the size and species composition of targeted fishes (McClanahan 2010). But on the other hand, ecosystems outside the MPA may become degraded as effort is reallocated and fishermen are squeezed into a smaller space, with both ecological and economic implications (Kellner, Tetreault et al. 2007; Botsford, Brumbaugh et al. 2009). The long term benefits of the MPA for fisheries management may be undermined by the reallocated fishing effort (Jennings 2009; Gaines, White et al. 2010).

The importance of fisher behaviour for understanding the impacts of closures is highlighted by Wilen et al. (2002). In their review of marine reserve simulation models, they find that almost all analyses of marine reserves have ignored the response of fishers to closures. These biological models either assume constant fishing mortality, the displaced effort simply disappears, or are limited to simple scenarios regarding the amount and placement of displaced effort. Models that incorporate realistic fisher behaviour can be significantly different from simpler models that only include biological information (Sanchirico and Wilen 2001). The implication of not including fisher behaviour is erroneous prediction of the efficacy of the proposed MPA. Furthermore, Therefore there is a fundamental need to understand how fishing effort is displaced or reallocated in the face of spatial management in order to be able to predict the impact of the MPA on fisheries and vice versa (Gaines, White et al. 2010).

Although a number of fisheries researchers have emphasised the need to understand fisher spatial behaviour for fisheries management in general terms (Hilborn and Walters 1992; Charles 1995; Hanna 2001; Wilen, Smith et al. 2002; Hilborn 2007), this area of research is underdeveloped compared to understanding the behaviour of fish stocks. Fisher spatial behaviour has been examined primarily in temperate commercial fishery contexts where spatial data exist (see Branch, Hilborn et al. 2006, for review), with some work conducted in tropical developing countries (Aswani 1998; Bene and Tewfik 2001; Abernethy, Allison et al. 2007; Daw 2008). Notably, there are few studies directly examining the displacement of fishing effort in response to MPAs in tropical contexts. It is of critical importance to understand the effects of MPAs on fisheries in tropical developing countries because of the number of people that depend on fisheries as a source of protein and income, the consequences of MPA implementation on people's livelihoods and the increasingly strong policy imperative to establish MPAs for biodiversity conservation.

The focus of this review paper is small-scale tropical developing country fisheries, and the objective is to examine the spatial behaviour of fishers and how it can be influenced by MPAs. Given there are very few empirical studies in this context, we also review the relevant literature and lessons learned in temperate systems. First, we examine aggregate patterns of effort distribution in small-scale tropical fisheries and highlight important differences between temperate and tropical fisheries. Second, we examine the factors that have been shown to affect fishing effort distribution, their complex interactions, and the heterogeneity of individual behaviour, and discuss the relevance of this to MPAs. We conclude by discussing how information and existing knowledge on spatial behaviour can contribute to MPA planning, design, and management in the tropics.

1.1. Understanding effort distribution in small-scale tropical fisheries

Studies of fisher behaviour and specifically spatial effort distribution are dominated by research in temperate commercial fisheries. These studies either examine aggregated fleet behaviour using assumptions from ecological foraging theory such as the Ideal Free Distribution (IFD) (Fretwell and Lucas 1970; Abrahams and Healey 1990; Gillis, Peterman et al. 1993), or more recently, using individual-based discrete-choice models to then predict aggregated effort distribution (Hutton, Mardle et al. 2004; Smith and Wilen 2005; Holland 2008; Valcic 2009). These studies use large national datasets of spatially-disaggregated catch and effort statistics as well as satellite data from vessel monitoring systems (VMS). These types of long-term, detailed fisheries data, which are standard to commercial temperate fisheries, are largely unavailable for their tropical developing country counterparts. This means that studies of fisher behaviour and effort distribution in tropical regions typically requires a different methodology for data collection and analysis.

Studies using approaches such as interviews, questionnaires and mapping exercises with fishers, asking what they do and why, have unveiled the heterogeneity, complexity and tradeoffs that fishers make when deciding where to fish (Daw 2008; Abernethy 2010). The heterogeneity of fisher behaviour captured is often missed in the data-rich modelling methods used in temperate contexts. Although modelling is a powerful method of analysis, a more qualitative methodology may be more appropriate than economic modelling to understand context-specific heterogeneity and complexity of behaviour (Salas and Gaertner 2004). *"If (Pita, Dickey et al.) goal is to understand and predict fishing behaviour and design more* *effective fishery management tools, it is critical to understand how fishermen actually make decisions , not how economic theory suggests they should make them"* (Holland 2008). Information on the social and cultural context is required to understand responses that often cannot be explained by economics alone (Hanna 2001).

Findings from interdisciplinary research on effort distribution in temperate fisheries can be a useful starting point for understanding tropical fisheries effort distribution (and displacement caused by MPAs). Profit maximisation and how this is constrained and traded off with the physical resources available, institutions present, access to information, fisher skill and experience, risk preference, competition and environmental factors have all been shown to influence effort distribution (Cove 1973; Johannes 1978; Acheson 1981; Gatewood 1983; Salas and Gaertner 2004; Smith and Wilen 2005; Christensen and Raakjaer 2006; Eggert and Lokina 2007). The range of factors that will determine location choice of tropical fishers may include factors that have been identified in temperate commercial fisheries. However, there are several characteristics common to small-scale tropical fisheries which are also likely to influence location choice.

In tropical developing countries, an added layer of complexity arises from the fact that heterogeneity in fisheries is high (Teh, Zeller et al. 2007; Williams, Ballagh et al. 2008; Cinner, McClanahan et al. 2009). They are characterised as being diverse in target species, gears and techniques, are very dynamic, changing seasonally and spatially, and there is often high variation in catches (Seijo, Defeo et al. 1998; Teh, Zeller et al. 2007; Daw 2008). Tropical fisheries often form part of diverse livelihood portfolios that tend to also include the agriculture and informal economic sectors (Allison and Ellis 2001; Sesabo and Tol 2007; Cinner and Bodin 2010). In addition to occupational mobility, migration to follow seasonal patterns of fish is prevalent in tropical developing countries (Aburto, Thiel et al. 2009) but which is often overlooked in studies of fishery dynamics. Furthermore, in temperate commercial fisheries, major technological advances (e.g. gear technology and fish finding technology) have largely been adopted, with limited opportunities for further revolutionary change. However, tropical fishers are rapidly gaining access to previously unavailable technologies, such as Geographical Positioning Systems (GPS), motorised vessels, and communications technologies (including mobile phones). The decision making processes of these fishers is a dynamic process, which may be changing rapidly in response to these developments (Adams, Mills et al. 2010). Tropical developing fisheries are therefore very dynamic in both the short and the long term is high, making these more difficult to predict than temperate large-scale fisheries.

Spatial effort distribution can be understood at the aggregated or fleet level in terms of overall patterns of distribution. A broadly supported generalisation which is relevant to MPAs is that effort is not uniformly distributed. In fact spatial distribution and intensity of effort has been shown to be patchy in both temperate and tropical environments (Béné 1996; Oostenbrugge, Densen et al. 2001; Pet-Soede, Van Densen et al. 2001). Beam trawlers in the North Sea demonstrate a highly aggregated effort distribution (Rijnsdorp, Broekman et al. 2000), a pattern shared by a wide range of artisanal vessels in Indonesia (Pet-Soede, Van Densen et al. 2001). Highly aggregated effort can be stable in time if fishers show inertia to change locations because of their experience of particular fishing grounds, but also due to the availability of fishing grounds and access to equipment such as boats (Bockstael and Opaluch 1983; Holland and Sutinen 2000; Eggert and Tveteras 2004; Smith 2005). Both industrial (Rijnsdorp, Buijs et al. 1998) and artisanal (Begossi 2001) fishers may demonstrate a high level of conservatism in fishing location. Likewise, Kenyan fishers with a small available reef area and without boats reported fishing the same grounds for several months at a time.

There are two ways of understanding effort distribution. 1. The aggregated approach described above, or 2. individual decision making which results in aggregate patterns. We now discuss the latter.

1.2. Factors influencing effort distribution

This section looks at the factors that influence fishing effort distribution and that need to be considered by spatial planners when predicting effort redistribution in response to MPAs. We have divided these factors into two types. The first are factors which exert the same influence on individual fishers and tend to relate to short run decision-making. The second are factors which are related to individual differences in fishers, tend to be associated with long run decisions, and hence are more likely to be the cause of the heterogeneity of responses to MPAs.

A key assumption made about fisheries is that profit maximisation is the main objective of where fishermen go to fish, leading to an effort distribution which maximises profit per unit effort. Clearly, artisanal fishing is an economic activity and fishers want to choose a location where they can catch the most fish or make the most money from fishing while minimising costs. However, empirical evidence is not always consistent with the assumption that fishers will fish in areas with highest profits relative to other areas (Gordon 1954; Botsford, Brumbaugh et al. 2009). Fishers may not distribute effort in proportion to profitability because they make decisions under uncertainty (Holland 2008). They make tradeoffs against variable costs, are constrained by the resource space and existing management. Knowledge of the resource distribution and where highest profits can be obtained may be imperfect (Pet-Soede, Van Densen et al. 2001), although fishers have strategies to minimise this through information exchange, and cooperative activities. Of course, daily fishing location decisions are also limited by a range of environmental and weather conditions. The degree to which fishers can mitigate against these effects is largely determined by the technological resources available (Wilen, Smith et al. 2002; Guest 2003; Smith 2005; Teh, Zeller et al. 2007; Williams, Ballagh et al. 2008). The limited technological capacity of many small-scale fishers constrains their daily operations due to weather and even seasonal weather patterns such as trade-winds can dictate, to a large extent, the resource space available to fishing. For example, the Southeast Trade winds affecting the Western Indian Ocean from June to October confines many small-scale fishers to shallow coastal lagoons.

At the simplest level there will be a maximum safely navigable distance, which will limit the size of the available resource space within which fishing locations can be chosen. This will vary with vessel type, weather conditions and personal perception of, and aversion to risk (see next section). Pet-Soede et al. (2001) showed substantial variation in the resource spaces of different fishing sectors in the Spermonde Archipelago, Indonesia, and several authors have documented a seasonal change in the size of the resource space of artisanal fishers with less distance being travelled rougher seasons or fishing areas changing in response to different monsoons (Oostenbrugge, Densen et al. 2001).

The costs and consequences of travel such as the cost of fuel or level of physical risk will tend to increase with distance from the landing site. Inputs such as fuel and engines may be related to credit availability, whereby fishers without access to credit may be unable to invest in a more powerful and efficient operation and thus may be constrained in terms of the distance they travel to fish (Guest 2003; Sesabo and Tol 2007).

Remote regions are also likely to be fished less intensively if they lack facilities to offload catches, maintain or replace equipment, process catch or procure bait. Additionally, travel time is valued according to its opportunity cost, which depends on the other potential activities on which fishers could spend their time. The time spent travelling to a distant fishing site, for example, could be spent fishing at a closer site, on an alternative economic activity or in recreation or family activities. Fishers with opportunities for rewarding activities will be more reluctant to travel far due to the high opportunity costs of the travel time.

The "friction-of-distance" concept has been used to understand the effect of distance on location choice and assumes an inverse linear relationship between distance and attractiveness of a fishing site. Such an approach has been used to model effort distribution and predict resulting patterns of effort distribution and resource abundance with increasing distance from a home port (Caddy and Carocci 1999). However, factors such as avoidance of other vessels, conflicts or gear theft, may increase the attractiveness of locations with increasing distance. Meanwhile, other aspects of distance are likely to have non-linear relationships between distance and site attractiveness. For example, perception of risk may exhibit a threshold effect whereby danger is perceived to increase suddenly on reaching a certain distance from where it no longer becomes possible to return home before nightfall. The perceived costs of travel time may exhibit thresholds related to the maximum storage time that can be spent without the need for provisions or ice; or the availability of daylight. The notion of geographic discounting proposed by Hannon (1994) provides a more complex concept of distance costs, incorporating both positive and negative effects of proximity (e.g. the convenience and disturbance of a nearby shopping centre) and resulting in a summed geographical discount rate that may be non-linear. Similarly, in fisheries, the range of non-linear costs and benefits of distance could be conceptualised as a non-linear geographical discount function incorporating thresholds and variable distance-utility relationships (Daw 2008).

Establishment of MPAs may increase the distance required to access fishing grounds- especially in circumstances where communities have placed MPAs nearby for easier surveillance. This, of course will be influenced by fishers access to capital equipment such as motorised boats and other factors that can impact spatial mobility. However, if the MPA is located near an access point such as a port, it may be the case that transport costs are minimised if fishing close to the MPA boundary yields high returns from fish spillover (Gaines, White et al. 2010). Rather than implementing a single large closure, several smaller closures may reduce the impact on fishers that have limited spatial mobility (Cinner 2007).

A range of formal and informal rules, and social norms restrict fishers' spatial behaviour. For example, fishing ground selection may be limited by customary marine tenure, through which communities exert exclusive rights to fishing grounds, a common feature in many regions of the Indo-Pacific (Aswani 1998; Johannes and Yeeting 2001; Cinner 2005; Cinner and Aswani 2007) and the Americas (Acheson 1975; de Castro and Begossi 1995; Begossi 2001) . Home community or social rank may determine both the techniques and ecological zones which can be fished by individual fishers (Ruddle 1996; Cinner, Marnane et al. 2005; Cinner and Aswani 2007). For example, Cinner et al. (2005) note that on Ahus Island, Papua New Guinea, individual and clan ownership of particular reef patches, and even rights to harvest certain species, can severely restrict where and how fishers can fish. Throughout the world, sacred areas, where fishing is not permitted have been observed (Johannes 1978; Cinner and Aswani 2007). Ethnicity, caste systems and family traditions have also been found to be important for location choice in peninsular Malaysia (Alam, Omar et al. 1996) and India (Coulthard 2008).

Fishers are trying to extract a resource they cannot see and although they may have a good understanding of local fish dynamics, they may only have a probabilistic knowledge of the value of the resource at each site (Allen and McGlade 1986; Robinson and Pascoe 1997). Fishers make decisions under great uncertainty and may use simple decision heuristics or 'rules of thumb' rather than utilitarian calculations (Holland 2008). Fishers may mitigate resource location uncertainty by using both official information (e.g. weather and wind forecasts) and exchanging information with other fishers. Cooperative fishing may reduce uncertainty and is usually associated with networks of fishers using similar fishing methods, close kin ties and long standing relationships, and often requires reciprocity (Acheson 1975; Gatewood 1984).

Cooperation and information sharing may also change seasonally. For example, fishers in the Yucatan fish independently and competitively when fishing is most lucrative, but cooperate and pool their catches the rest of the year when fishing is poor (Salas 2000). Competition may preclude information sharing but information may also be subversively gained through finding out what other fishers have caught and where (Durrenberger and Palsson 1986) or using the location of other boats as an indicator of fish location (Cove 1973).

The rate and effectiveness of reorganisation of fishing activities following displacement caused by an MPA will depend on fishers' access to information. Access to formal and informal information regarding changes within the MPA (e.g. increasing biomass) and potential for spillover may drive 'fishing-the-line' behaviour. Displaced fisheries which are characterised by a high level of information sharing and cooperation may adapt more rapidly to change and are less likely to be affected by conflicts emerging from shifts or concentration in effort than more competitive fisheries. However, areas used for cooperative fishing may be more sensitive to displacement and should be considered in MPA planning.

1.3. Individual differences and heterogeneity in response to MPAs

A number of studies have examined factors influencing longer-term choices of entry and exit into fishers (Pollnac, Pomeroy et al. 2001; Salayo, Garces et al. 2008; Cinner, Daw et al. 2009; Pita, Dickey et al. 2010). Although this is very important for determining the amount and distribution of displaced effort from MPA implementation, here we are interested in spatial behaviour of fishers that remain in the fishery. This section examines individual differences that exist within fishing fleets and how this heterogeneity may influence response to MPAs.

Firstly, the availability of fixed inputs such as vessel size, engine size and gear type, and individual ability, experience and wealth will enable or constrain the resource space of different fishers (Williams, Ballagh et al. 2008). Secondly, individual profit maximisation may not always be a fisher's sole motivation. Fishers may aim to meet a target level reward rather than aim to maximise rewards (Cabrera and Defeo 2001; Abernethy, Allison et al. 2007; Holland 2008). Guest (2003) found that even the poorest of Ecuadorean shrimp fishers will not go fishing unless a certain monetary minimum is expected to be met. The few fishers who continued to fish when catch rates are low were not the poorest fishers, but fishers who fished because they love to. Similarly, on the island of Anguilla in the Caribbean, a set of fishers were found to value their leisure time over trying to maximise their profit (Abernethy, Allison et al. 2007). Fishers have also been observed to concentrate on meeting a quota of catch per month to retain membership in a cooperative (Salas 2000), or fish a certain number of days to be able to claim unemployment insurance (Roy 1998). Additionally, individualistic profit maximising may be constrained and traded off with the other factors described below.

Third, underpinning an individual's fishing strategy and decision-making is the way they respond to physical and financial risks. There have been many studies examining financial risk behaviour and risk preferences of fishers, with most being located in temperate commercial fisheries. This has been studied primarily by looking at the variation in catch, with fishers who seek high variation indicating risk-seeking behaviour (Bockstael and Opaluch 1983; Dupont 1993; Mistiaen and Strand 2000; Smith and Wilen 2005). It has been experimentally shown that fishers tend to favour consistency of catch over large but uncertain profits (Holland 2008). However, recent economic research has cast doubt on such small stake experiments, in which the difference in rewards between choices is small. For example, Eggert & Martinsson (2004) found that half of Swedish fishermen respond in a manner inconsistent with risk aversion and that risk aversion is not an important influence on choice among locations. Eggert & Tveteras (2004) found that 30% of Swedish trawlers were actually risk neutral, a finding supported by research by McConnell and Price (2006). Holland & Sutinen (2000) found risk seeking behaviour, but noted that fishermen may try to reduce risks in ways not captured in their model. Strand (2004) found that fishermen's risk preferences differed between regions: New York fishermen were risk averse, while Florida Keys fishermen were risk neutral. An ethnographic study undertaken by Holland (2008) showed that risk preferences among groundfish fishers in New Holland are highly variable. Some fishermen stated the more money they have, the more risks they can take, while other fishers stated that they take more risks if they are under financial pressure. There are clearly very heterogeneous and context-specific risk preferences among fishers, and the assumption that fishers are risk averse is not consistent across research (Eggert and Martinsson 2004).

Less is known about risk preferences of small-scale fishers in tropical developing countries. Some fishers have been shown to sacrifice high catches to minimise physical and financial risks by choosing to fish grounds that are close to the community, and using fishing gears that have low operating costs (Seijo and Defeo 1994; Helu, Anderson et al. 1999). Cabrera and Defeo (2001) show that some small-scale shell fishers consistently select locations close to their home port, regardless of previous catch, while other fishers will only stay if catch remains high. Wealth has been shown to influence risk taking, with greater wealth resulting in more risk taking activities (Sesabo and Tol 2007). Other studies show that livelihood characteristics can be more important for determining risk preferences than wealth (Holland 2008) such as the level of dependence on the resource (Gelcich, Edwards-Jones et al. 2007).

Determining the risk profile of fishers can provide important information for MPA design. The impact of risk preferences should be considered when designing MPA policy that will influence behaviour by altering the relative profitability and reliability of fishing locations or strategies. For example, if MPAs are chosen with low mean and low variance in yield, then risk averse (and by implication poorer) fishers, may be worse off. The fact that these fishers own vessels without motors implies a limitation of accessible substitutes, which may further intensify poverty.

1.4. Discussion: Implications of fisher behaviour for MPAs

Few studies have specifically examined the behavioural response of fishers to MPA implementation and displacement of effort. While most information comes from temperate fisheries, and often involves modelling in data-rich contexts, again this can be used to inform patterns of change forced by MPAs in tropical fisheries. From the increasing body of knowledge on location choice leading to patterns of effort distribution, it is also possible to identify important factors and their implications for the design and management of MPAs affecting small-scale fisheries in tropical regions.

A study undertaken on the Oregon bottom trawl ground fishery examined the simulated response of fishermen to MPAs and the actual response of a real closure. Analysis of spatial behaviour found that fishermen chose locations based on profit, distance and experience. The model however, incorrectly predicted redistribution of effort as it was lacking important habitat information (Valcic 2009). The effects of habitat on patterns of reallocated effort following displacement are likely to be complex in tropical fishery contexts given the high levels of heterogeneity in these environments, particularly coral reefs. Critically, the Valcic (2009) study revealed that closing an area to fishing meant that the decision-making processes that fishers used were fundamentally changed, which further complicates predictions of response to MPAs.

Based on assumptions of perceived spillover, 'fishing-the-line' is often predicted or observed as a response to MPA implementation (McClanahan and Kaunda-Arara 1996; Pauly, Christensen et al. 2000; Walters 2000; Dreyfus-Leon and Kleiber 2001; Kellner, Tetreault et al. 2007). Fishing near MPA boundaries can result in larger catches and/or catches of larger fish (Russ, Alcala et al. 2004), and well-established MPAs can lead to increased revenues for adjacent fisheries (McClanahan 2010). Intensity of fishing near MPAs can provide benefits for some fishers, but the consequences for the fishery and protected stock are less clear (Kellner, Tetreault et al. 2007). In some studies, effort has been shown to aggregate at the boundary of the MPA and then decrease with distance from the MPA (Murawski, Wigley et al. 2005; Goni, Quetglas et al. 2006). As a result, modelled and empirically observed responses to MPAs that invoke spillover are often based on the assumption that effort will redistribute according to expected profitability.

Attempts to predict the response of fishers to MPAs implemented in tropical regions will likely be undermined by heterogeneity in behaviour and a limited understanding of ecological processes and their responses to protection. Ad hoc assumptions about reallocation of effort means that predictions about the efficacy of a MPA can be wide of the mark (Wilen, Smith et al. 2002) or even biased, with MPAs appearing to be more attractive because the true response and costs are underestimated (Smith and Wilen 2003). Responses in multi-species, multi-gear fisheries common to ecologically complex coral reef ecosystems may be particularly difficult to assess and predictive ability will be further confounded if decision-making processes fundamentally change in response to the MPA (Valcic 2009). Nevertheless, an understanding of the factors underpinning location choice in different groups of fishers will be informative in anticipating and coping with changes in behaviour. In the first instance, an understanding of effort allocation by fishers can be used to design closed areas based on existing patterns of use and minimise negative effects (Aswani 1998). Knowledge of spatial patterns in gear use will also be beneficial to the design process (Forcada, Valle et al. 2009) and MPAs may need to be gear specific (Teh, Zeller et al. 2007), particularly in the multi-gear contest of many tropical fisheries. Information on the fishery can be combined with ecological information on habitat heterogeneity and critical habitats such as spawning aggregation sites (Domeier and Colin 1997).

In reviewing the main factors determining fisher location choice, we have identified their implications for changes in fisher behaviour caused by MPA implementation. These implications provide a foundation for developing methodological tools and assessment approaches that will be useful for MPA planning and monitoring. At least, consideration of the main factors and their implications will inform the planning process and enable changes in fisher behaviour to be anticipated. All of the factors identified are potentially important in determining the response of fishers to MPA displacement but are expected to change in relative importance over time from implementation. Certain factors will be more important in the planning and design process while the relevance of others may increase during implementation. For example, when conditions for spillover are met following recovery of biomass, 'fishing-the-line' may develop if fishers are motivated by profit maximisation.

Table 1.1. Factors affecting the spatial behaviour of fishers and their implications for MPA design and management.

Factor	**Implications**
Profit maximisation (or minimum variance preferences)	Where profit maximization is a weak motivation for engagement in the fishery, 'fishing-the-line' behaviour may not develop Changes to costs and profits of fishing after MPA implementation are dynamic: short-term impacts may cause initial displacement and reallocation of effort; if conditions for spillover are met, there may be further reallocation
Travel costs, distance and resource space constraints	Size and position of MPA in resource space may change distances to fishing grounds, affecting costs and profits and other impacts *Impacts of and behavioural responses to MPAs will vary as attractiveness of fishing sites is not inversely related to distance*
Institutions	Informal rules and social norms common to many small-scale fisheries will inform MPA design, particularly those that are spatially explicit or restrict access MPA infrastructure (e.g. demarcation buoys) may conflict with local customs and taboos and must be carefully considered
Information, cooperation and experience	Information, cooperation and experience may promote adaptation to MPAs in finding new grounds, sharing expertise and reducing uncertainty Knowledge on levels of competition, conflict and cooperation within and between affected fisheries will inform MPA design and understanding of fisher responses to reduced resource space *Areas used for cooperative fishing may be more sensitive to closures???*
Environmental factors	MPA design should consider seasonal patterns in resource space use; MPAs sited on poor weather fishing grounds may be more sensitive Seasonal or weather-affected access points should be carefully considered in MPA design *Seasons may affect market demand (e.g. tourism) and may act synergistically with other factors in determining MPA impacts*
Individual personality and	Risk profiling can inform MPA design and management Fishers with certain psycho-cultural characteristics (e.g.

heterogeneity of behaviour (Risk preferences,	exploratory and risk taking behaviour) may adapt more effectively to MPA implementation Positioning MPAs close to shore/access points may disproportionately impact risk-averse fishers Other value systems may be equally or more important than profit: assumptions regarding profit maximization or minimizing variance of catches in MPA designs may poorly reflect fishers actual

On implementation of an effective protected area, fish populations and habitats within and adjacent to the MPA will continue to change through ecological processes and patterns of fishing mortality and selectivity. Fish population recovery inside tropical MPAs may take decades (McClanahan and Graham 2005; Babcock, Shears et al. 2010) and suggests reorganisation of fisheries can be expected to occur over long time frames. Assuming that enhancement of yield cannot be achieved until conditions for spillover are met, in the short-term, displaced fisheries will enter a regime of reduced yield and revenue unless reorganisation can occur through various means, such as changing gear or fishing location, increasing effort (if fisheries are not overexploited) and increasing access to markets.

In spite of any attempts at predicting or anticipating effort reallocation following displacement, externalities can be major drivers of fisher behaviour and are largely unpredictable. These include changes in fuel price, technology and markets(Abernethy, Trebilcock et al. 2010). Rather than reallocating effort in adjacent fishing grounds, entire fleets can shift location as occurred following the imposition of a closure in Lyme Bay in SW England (S. Jennings, Pers comm.).

1.5. Concluding comments

Clearly there is a need to understand fisher behaviour better especially in tropical developing country context. Ethnographic and qualitative approaches are also are important for understanding fishers behaviour, especially in the tropics where there is limited quantitative data (such as catch and effort, satellite-tracking data) available which are available in temperate developed nations fisheries. Although this review is focused on MPAs, understanding how fishers are displaced is of more general importance due to an increasingly crowded ocean due to the growth in other marine activities such as wind farms and aquaculture.

Chapter 2. Methodology and Study sites

This study used a wide range of qualitative and quantitative methods to collect information about artisanal fishers' spatial behaviour. Qualitative interviews, focus groups and participant observation were used for exploratory, inductive research into the nature of fishing activities and spatial decision making. Participatory mapping was used in Kenya to provide a base map that would be relevant to fishers. A structured survey and associated individual mapping collected information on the behaviour of a sample of fishers, and a participatory GPS tracking and logbook programme provided detailed spatial and temporal observation of the activities of a smaller group of collaborating fishers over a longer timespan. Due to the challenges of studying spatial behaviour in artisanal fisheries, considerable methodological innovation and experimentation were required. This section describes the location of study sites, each of the methods and the types of data generated.

Table 2.1. Summary table of sample sizes for each methodology.

	Seychelles	Kenya
Key Informant and FG interviews	9	6
Participant observation	3	12
Participatory mapping		5
Survey and surveymap	62	132
GPS tracking - # fishers	4	33
GPS tracking - # fishing trips	84	1134
With complete tracks		621
Logbook data	44	1313
With associated tracks	44	737
With complete tracks		422

2.1. Study Sites

This study gathered data on spatial behaviour of fishermen at locations in Seychelles and the South Kenyan coast (Figures 1 and 2). In Kenya sampling of fishers was in discrete landing sites, while, due to the lower numbers of fishers in Seychelles fishers were sampled from around the coastline of the two main Seychelles islands (Mahe and Praslin) and divided by region.

In Seychelles, a list of all registered boats was available in the Seychelles Fishing Authority (SFA) database. The boat owners from the list were contacted. If interested, the boat owner or the boat skipper (if the boat owner was not a fisherman himself) was interviewed either on site or at SFA. We also got 1 or 2 fishermen on site who participated in survey after seeing their fellow fishermen participating, and these could also be non-registered fishermen.

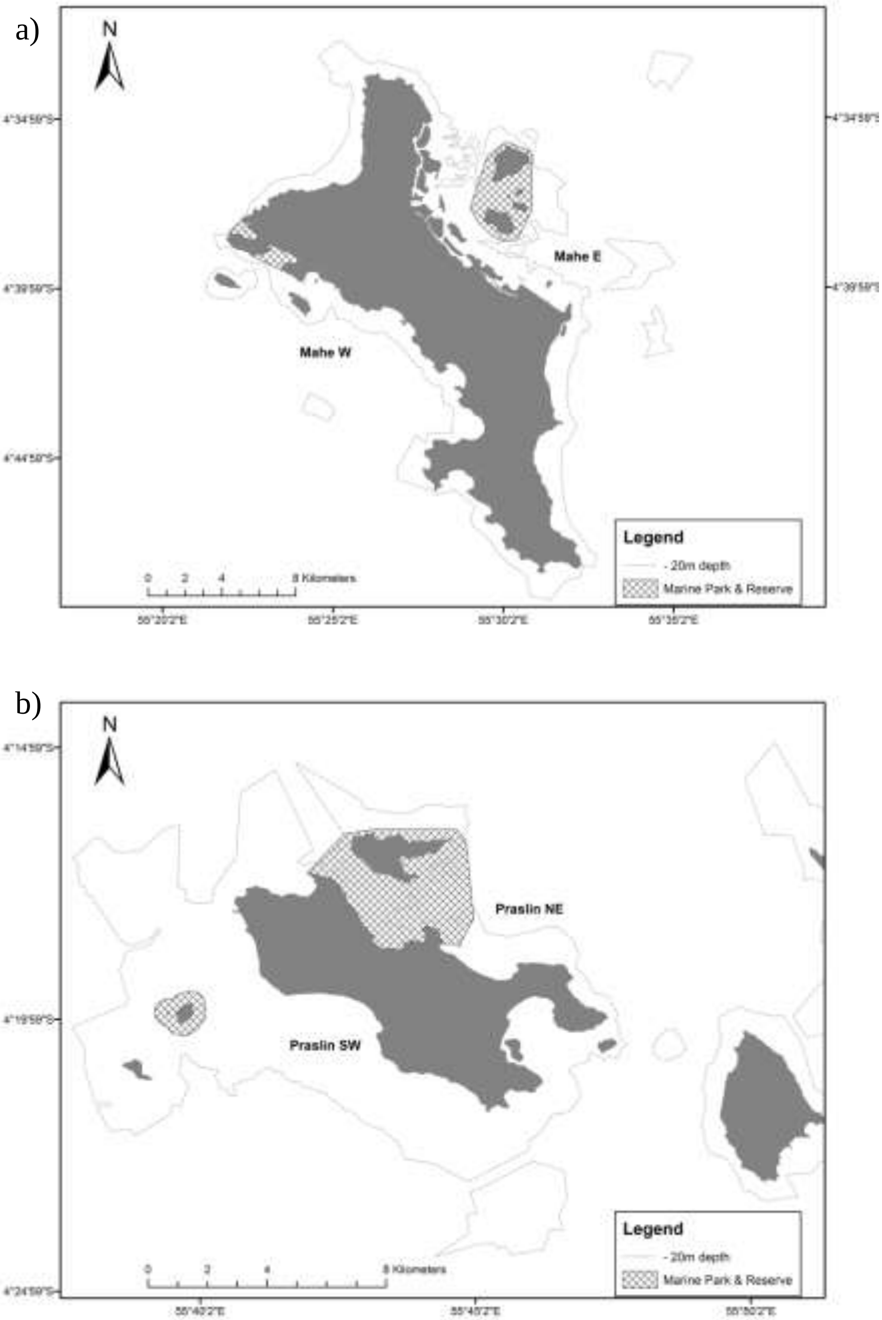


Figure 2.1. Map of study sites and closure locations in Seychelles, a) Mahe, b) Praslin

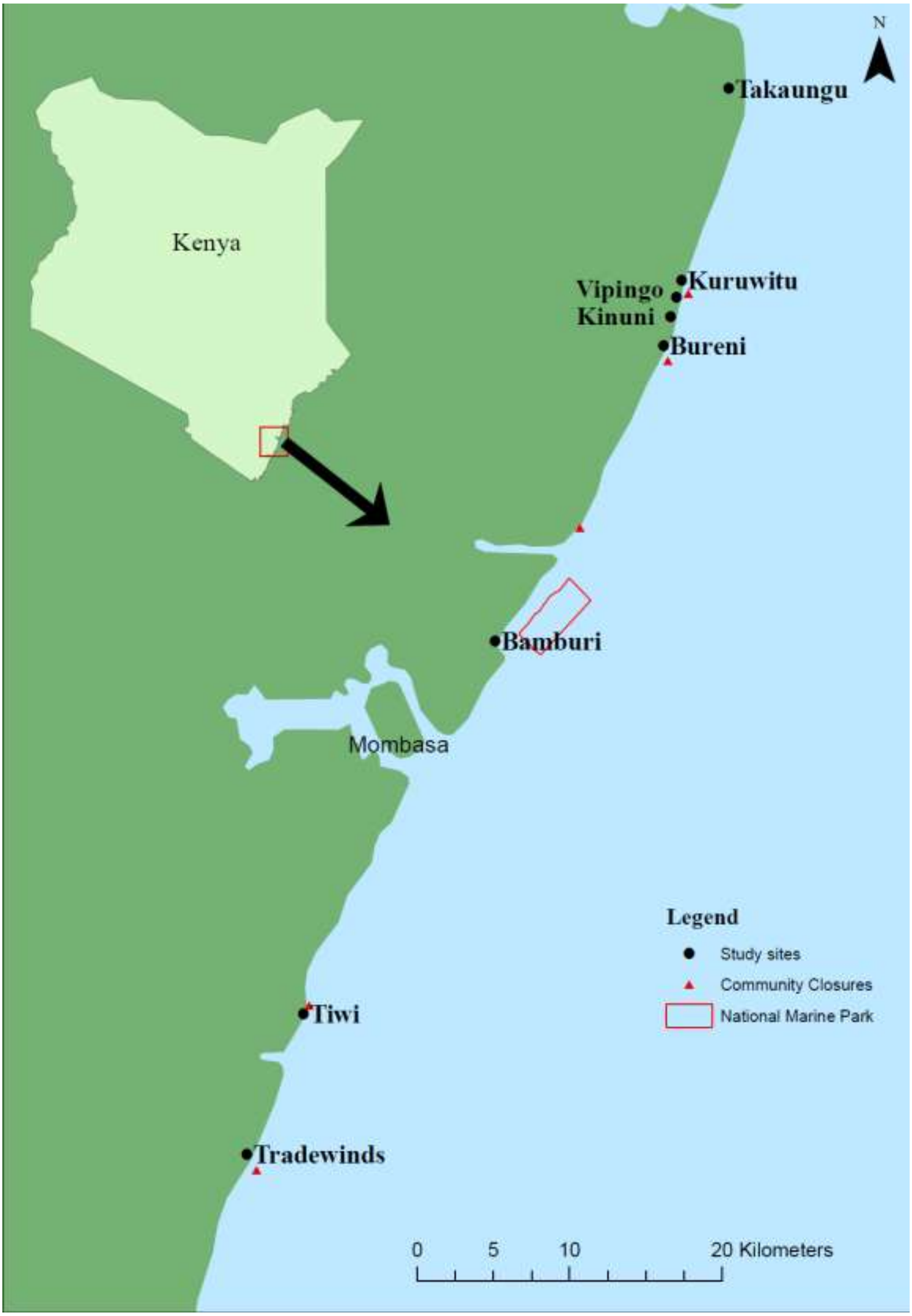


Figure 2.2. Map of study sites and closure locations in Kenya

Table 2.2. Sites in Kenya with details of management and size of the management area.

Site	Management	Closure size	Comments
Bamburi	Nationa park	10 km	Compliance

Tradewinds	Tengefu	11.8 Hectares	Low compliance
Takaungu	No management		
Kuruwitu			Within Kinuni tengefu
Tiwi	Tengefu	12.5 Hectares	Compliance
Kinuni	Tengefu	29 Hectares	Compliance
Vipingo			Within Kinuni tengefu
Bureni	Tengefu	5.2 Hectares	Low compliance

In Seychelles fishers were targeted who were part of the fleet of small outboard engine-powered fibreglass boats (known as 'Mini Mahes'). Engine size is typically 25-40 horsepower and the most common gears in use include handlines, traps and small seine nets for shoaling mackerels. For this study we focussed on the behaviour of handline and trap fishers.

Figure 2.3. Typical Mini-mahe fishing operation handlining in Seychelles.

Sites were chosen in Kenya to include sites with and without protected areas, and to have a dominance of small-scale fishers using either hand lines, nets or spearguns. Fishers included those with or without vessels or fishers fishing from small paddled canoes, surfboards or small sailing vessels.

Figure 2.4. Fishers in Kenya Net fishing without a vessel, and a typical sailing vessel or **Ngalawa**

2.2. Qualitative interviews

Due to the limited knowledge about spatial fishing behaviour in the Western Indian Ocean Region, the project commenced with qualitative interviews with either focus groups or key informants in both countries. These interviews followed a standard guide, which had been modified for each country by national experts at a project inception workshop (Appendix). In discussion with country teams it was decided to pursue mostly key informant interviews in

Seychelles and focus groups in Kenya. There were 7 focus groups and 9 key informant interviews done in Kenya. Interviews were either audio recorded and transcribed or written up from interviewers' notes and then thematically analysed according to different aspects of spatial decision-making in a qualitative data analysis software (NVivo).

2.3. Participant observation

To improve our contextual understanding of the fishery and to support triangulation of other data sources, team members accompanied fishers on individual trips. During the trip fishers were asked about their normal behaviour, and the reasons for spatial decisions that were made. Reports of participant observations comprised of a rich description of the activities, conversations and observations.

2.4. Participatory mapping

In Kenya, base maps of the marine environment around each landing site were prepared from Google Earth images in collaboration with small groups of expert fishers through a Participatory GIS (PGIS) process. PGIS involves using maps, aerial photographs, or processed satellite imagery as a template on which spatial information on cultural, economic and social aspects can be elicited from communities. Orientation on drawn maps can be difficult to most people, fishermen and researchers alike, hence the use of images in PGIS. PGIS aims at placing control on access and use of culturally sensitive spatial data in the hands of those who generated these thereby protecting traditional knowledge.

Methods

The initial step was to review available spatial information on study areas. Red-Green-Blue images of near shore areas and lagoons were extracted from Google Earth (pro version 4.2.1) and printed in colour. The coastline was divided into small areas so as to increase the level of detail in the images. In order to capture as many views and local knowledge as possible, in each of the sites, a group consisting of representatives from fisher who use different fishing gear (spear, net, trap and line) was constituted at the landing sites. Sampling was done to capture a representation of both young and old fishers.

Sampling procedure

We informed the fishermen that we will be having a PGIS meeting a week prior to the date. We had the meeting after the fishers were from their normal fishing activities. First we listed the name of all the fishermen present with their different fishing gears and age. We then grouped the fishermen according to their gears (net, hook and line, spear and traps) and then ages (<35 or >35). We selected the 1st person from each group and Came up with a group 8 people. We divided the group again into two groups of four fishers each.

The fishers were orientated with the map and once it was clear they able to identify various locations, they were asked to annotate on the images and draw points to represent landing sites, submerged objects, reef openings and items of interest on land e.g. beach hotels and beaches, meeting places (meeting trees), geo-morphological features such as cliffs and reef openings (*Mlangos*), and to draw polygons of different texture/patterns to represent coral, sea grass, sand, and mixed habitats. They also listed the gear used in each of the coastline segment, although different types of fishing are practiced during different times of the year. Each mark on the map (point or polygon) was assigned a reference number which was linked to a name and explanation.

The images/field templates were scanned and geo-referenced using coordinates for distinct locations on the images using Google Earth. The distinct locations used included road

intersections and building edge on land and cloud/wave edges in the water. An average root mean squared error (RMSE) of 0.000191 was obtained for each geo-referenced map.
The next step was to perform onscreen digitizing of the markings made on the images. Two GIS shape-files, one for polygons and the other for points were created. Polygon drawings on the images and points were traced and corresponding data entered in the respective shapefiles attribute table.
While formal maps may accurately chart a landing site's and fishing grounds geography, maps drawn by landing site users are meant to emphasize parts of the landing site or locations of interest they perceive as most important or most accessible. The participatory mapping resulted in annotated Google Earth base maps with locally recognisable features labelled with local names which covered the entire coastline where Kenyan surveys were done.

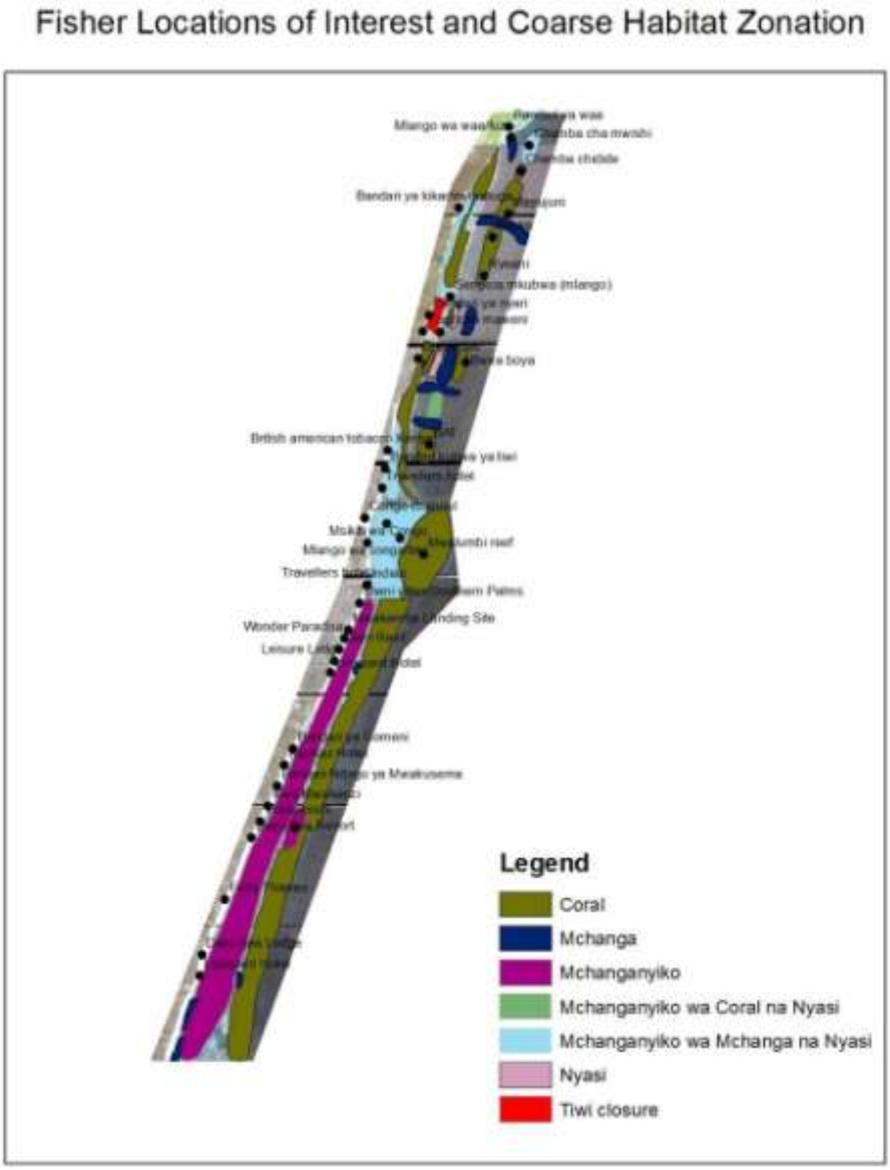


Figure 2.5. Example of a map of the study area with the image, points and polygons representing spatial attributes in the south coast.

2.5. Survey

Based on findings from the qualitative interviews, a survey instrument was designed to capture standardised data about the spatial behaviour, navigation, communications, and experiences of closed areas from a large number of fishers in each country.

In Kenya, at each site we first developed a list of fishers and the gear they use with the help of the Beach Management Unit (BMU) chairperson and other fishers who were BMU members and non-members. From the list and with the assistance of knowledgeable fishers we randomly sampled fishers who make spatial decisions for the purposes of interviewing them. In most cases, the respondents were either captains, fishers who carry the project's GPS where applicable (the south coast sites did not have GPS yet) or those who fished on their own or were allocated responsibilities by the captains. We did not interview part-time fishers, fishers who exclusively use ringnet, castnet or octopus hook. Where fishing spatial decisions were made at various levels, a cross section of respondents were identified and interviewed. Survey data were entered into an Access database.

Table 2.3. Number of respondents by country and by site.

Country	Site	Number of respondents
Kenya	Bamburi	20
	Bureni	14
	Kinuni	12
	Kuruwitu	18
	Takaungu	18
	Tiwi	20
	Tradewinds	17
	Vipingo	13
	Total	**132**
Seychelles	E Mahe	32
	W Mahe	10
	NE Praslin	11
	SW Praslin	9
	Total	**62**

2.6. Survey Map

To provide an indication of the distribution of fishing effort by a large sample of fishers in each country, surveys were accompanied by a mapping method in which fishers were asked to broadly indicate where they normally fish with each gear, in each season on a base map. In Kenya A4 sized annotated Google Earth images from the participatory mapping exercise were numbered and glued together on an A0 piece of paper to provide a continuous map of the coastline and nearshore habitat in each area. In Seychelles the base maps were a series of laminated images from navigational charts showing islands, emergent reefs, key land-based navigational features, rocks, depth soundings and approximate bathymetry, overlaid with a numbered 1.7km grid.

In Kenya responses were recorded by drawing them onto A4 acetate sheets which were then labelled with the interview code, question number and map number. During the interview the landing site was used as a starting point. The fisher then indicated South or North of the landing site as to where he does his fishing for different reasons (type of gear, season, displacements, depth , habitat etc).A different acetate was used for each image. The map number, name of the interviewee and the question being answered were also noted on the acetate. Corner placeholders for the map image were marked and the acetates were stapled to the survey.

Surveymap data were entered into the same Access database along with survey questions. In Seychelles each surveymap shapes was entered into the database by entering the appropriate grid squares and map number, while in Kenya shapes were digitised into Arc by affixing them to a computer monitor and aligning them with digitised versions of the survey maps on the screen. The shapes were then traced through the acetates and saved as new features.

2.7. GPS and logbook monitoring programme

A major focus of the efforts of the project was to collect detailed spatial information on the fishing behaviour of a smaller number of cooperative fishers over a long time period. This provided accurate indications of fishing activity, free from biases or errors inherent in map based, or reported data. GPS monitoring also indicated temporal variation in spatial behaviour (rather than average or general trends) and allowed individual trips to be studied. An accompanying logbook scheme allowed characteristics of each trip (e.g. gears, catches, numbers of fishers) to be recorded. Figure 2.6 summarises the stages and activities involved in running the participatory GPS and logbook monitoring.

Introductory Meetings

An introductory meeting for the project was conducted in each of the study sites to introduce the project and ask the concerned authority (Beach management unit leadership) on the possibilities of conducting the study in their area. The objectives of the study were highlighted to familiarise the fishers on the expectations of the projects. This was particularly necessary for the fishers to judge if they were capable of participating in project. The meetings generated a list of the fishers who were ready to volunteer in the data collection, and an agreed date for GPS training.

GPS training

The objective of the training was to expose the fisher to the basics of using the GPS device in the field. Although a GPS device has multiple functions the training was focussed on the functionalities limited to the study, this was necessary to reduce the GPS operation time for the fisher and to avoid accidental loss of data through mishandling of the device. The topics covered in the GPS training included:

- What is a GPS
- How a GPS device works
- Parts of the a GPs device
- Changing GPS device batteries
- Taking care of a GPS device
- Solving common problems experienced in the field
- Procedures for completing daily fish trip logbook.

Logbook data

The fisher’s logbooks were the basis for monitoring fish catch and fishing characteristics for each trip. Each fisher was requested to enter date, landing site, time start, time end, vessel type, crew size, fishing gear , fish weight, catch value, type of fish, sea condition the GPS performance during the trip after returning from each fishing trip. Participants who could not write were helped by fellow crew or family members to fill in the logbooks.

Monitoring

Thirty fishers were recruited and given a hand held GPS unit (Garmin Geko 201) which they kept on during their fishing trips. The units could save up to 10,000 points. The GPS was set to record track points between 1-2 minutes. Thus the GPs could save up to 166 hours of tracks data. This resulted in a 10-day data download cycle. Fishermen were given a 10 page logbook that was collected at the same time as the data from the GPS was downloaded onto a field laptop computer. The data collector examined the logbook so as to correct any obvious error and issue out a new set of logbook.

GPS track data were downloaded in the field as text files of individual points using the freeware DNR Garmin (created by the Minnesota Department of Natural Resources). Each point was downloaded with latitude, longitude local time and time in UTC.

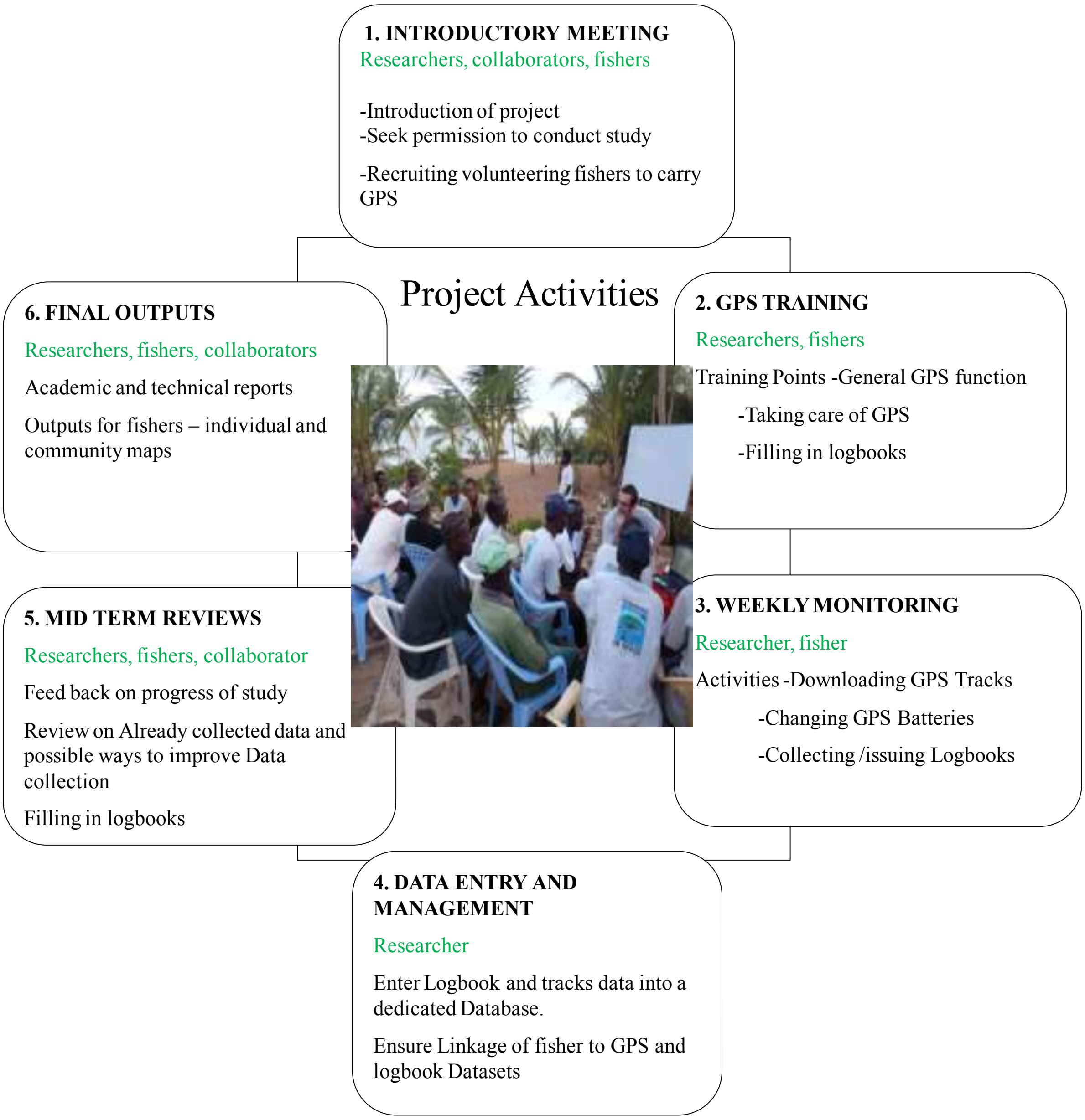


Figure 2.6. Outline of the procedures for the GPS and logbook monitoring. People involved in each stage are highlighted in green.

The GPS monitoring method was developed throughout the project and raised a range of practical and data issues, which are discussed in detail in Appendix 4.

2.8. Data processing checking and analysis

GPS points were transferred from the downloaded text files into an Access database. Logbook data were entered into the same database and an Access form and query were used to associate the logbook data from each trip with the appropriate points based on time, GPS unit and fisher. Where GPS points had been recorded for a trip with no accompanying logbook record, the trip was identified from the points stored on the GPS and associated with a new manually-created trip. Care had to be taken to correctly delineate trips which occurred overnight.

All spatial data were related to 25, 50 and 100m grid cells to allow summary comparison and analysis between different datasets. These grid cells allow the spatial fishing data to be linked to spatial characteristics such as distance from shore, distance from closure and to data from habitat mapping etc. GPS point data required considerable data processing and checking. Land masks were created and used to exclude points on land. Time and distance between each point, and speed was calculated for each point to identify trips with missing or erroneous sections, or erratic recording behaviour by units. Trips flagged in this way were re-examined by plotting them in GIS over Google Earth images.

Analysis of spatial fishing effort distribution data ideally includes identification of fishing activity distinct from navigation or search activities. In studies on industrialised fisheries analysis of the speed of travel has been used to probabilistically determine those points based around fishing (Lee, South et al. 2010). Such techniques are complicated in this study due to the diversity of gears, vessels and fishing behaviour included in the study. Future analysis of the collected data will focus on differentiation of fishing points by analysis of speed for each gear and vessel-type (e.g. Figure 2.7), informed by interviews with fishers about their behaviour during particular plotted trips.

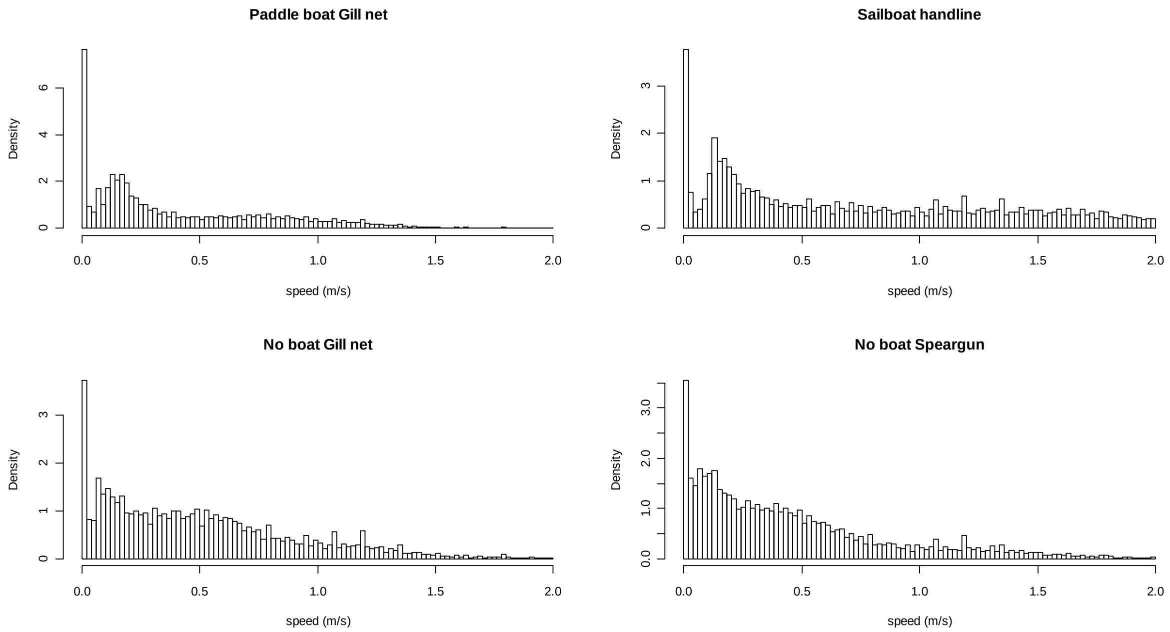


Figure 2.7. Speed frequency distribution for GPS points by vessel and gear type. Modal analysis of such data can facilitate the identification of fishing and non-fishing sites, with higher speed nodes assumed to represent navigation rather than fishing.

The delineation of land-masks to exclude points was problematic in some cases given the possibility of nearshore fishing activities by certain gears e.g. speargun. For example, it is possible for a spear fisher to be fishing at one location during high tide which could be dry and walked over during low tide. Placing the land mask too close to land (e.g. at the high-water mark) might lead to points from walking over the reef at low tide, or from activities on a boat moored on the reef flat being characterised as at-sea-fishing activities. Meanwhile positioning the land too far from land (e.g. low-water mark) might exclude genuine fishing activity conducted at high or neap tides.

The general understanding of fishing patterns afforded by participant observation was useful for the interpretation of the GPS data. However with hindsight they could have been more valuable had the observer and the fisher both carried GPS units and the observer had noted activities being conducted at each point in time.

2.9. Ethical considerations and clearance

Ethical considerations of the project and procedures were reviewed and approved by the University of East Anglia International Development Research Ethics Committee.

Personal fishing behaviour represents individual knowledge which is a valuable asset. Data was thus only presented in an aggregate form, and the specific locations of fishing spots is obscured by presenting fishing effort by grid cells rather than points. Individual data was shared with the individuals concerned, but was protected by storing in an anonymised form.

Due to the long-term (>1year), consistent involvement of fishers for the monitoring, the poverty of the communities involved, the responsibility to look after equipment (GPS receivers) and the effort required to participate with the project, some locally appropriate compensation was made available to participants for their commitment and effort. Compensation was in the form of provisions and a gift of a project T-Shirt provided at a flat rate to reward conscientious cooperation with the project in general, rather than rewarding for each day of data collected, to avoid ‘paying for data’. To recognise the cooperation of the communities, refreshments was provided for the participants during meetings, and a token gift was made to fisher associations at the host communities, where it was felt that they were representative and supported by the majority of the community.

Chapter 3. Where do fishers fish?

The first basic question that was addressed by this study was a descriptive account of where fishing effort was allocated in each of the study sites. Surveymap and GPS monitoring provided indications of fishing grounds and spatial constraints on fishing effort distribution.

3.1. Fishing ground distribution as indicated by Surveymap data

Despite the uncertainty around the absolute accuracy of the surveymap data (See Appendix 5. Validation of the Surveymap data, the method allowed rapid description of aggregate patterns of effort distribution based on large numbers of fishers. In Seychelles clear spatial segregation between the fishers from the two main islands are clear. In particular fishers from Praslin did not report fishing near Mahe or Silhouette (NW of Mahe) islands (Figure 3.1). Meanwhile, Mahe fishers did report fishing near the western end of Praslin, but not around eastern Praslin or the islands to the east of Praslin such as La Digue. Concentrations of fishing effort were indicated by Praslin fishers off the south shore of Praslin, probably related to known rabbit fish (*Siganus sutor*) spawning aggregations (Robinson, Samoilys et al. 2011). For Mahe fishers, effort was concentrated on a system of reefs and rocks lying northeast of the northern point of Mahe, and effort generally was higher north and east of Mahe and around Silhouette than southwest of Mahe. This reflects the higher numbers of fishers interviewed from E Mahe. As this sampling distribution reflects the actual abundance of fishers on E and W Mahe, maps in Figure 3.1 probably correctly reflect lower density of effort west of Mahe. The displacement from the largest marine parks is visible in northern Praslin (Curieuse) and E Mahe (St Anne) as low or zero effort density areas, although there is no evidence of displacement from the marine park around Silhouette island. Mapping of Praslin fishers activity in northern grounds appears to have been limited by the extent of the maps. Some clumping of effort delineated by clear N-S or E-W breaks may have been created as a result of the boundaries of the maps used during the interviews and may not reflect actual discontinuities in effort density (Figure 3.1).

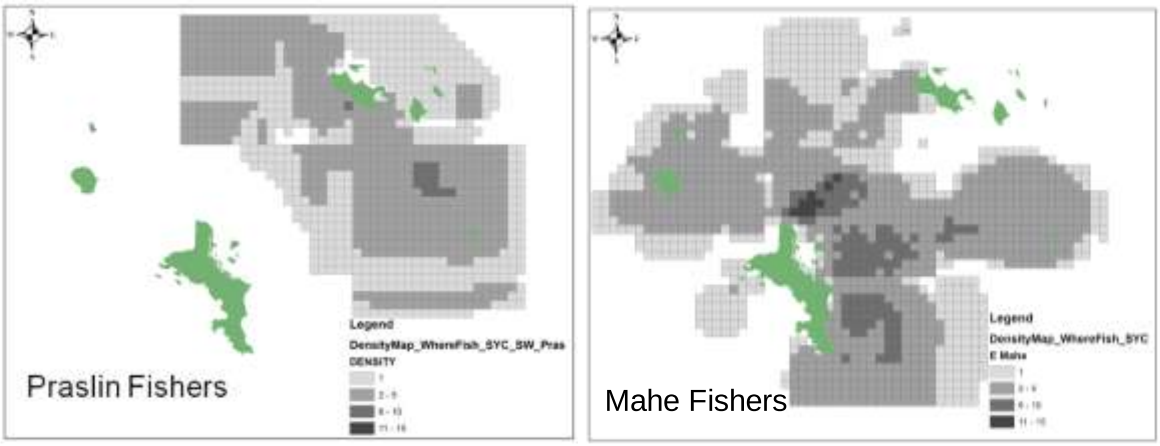


Figure 3.1. Aggregate results of survey map fishing areas from 62 fishers in Seychelles.

Surveymap data aggregated by gear in Kenya illustrates the nearshore pattern of spatial effort distribution. In the cluster of sites of Kuruwitu, Vipingo, Kinuni and Bureni, effort was focussed within 2000m of the shore with limited use of habitats beyond the edge of the reef.

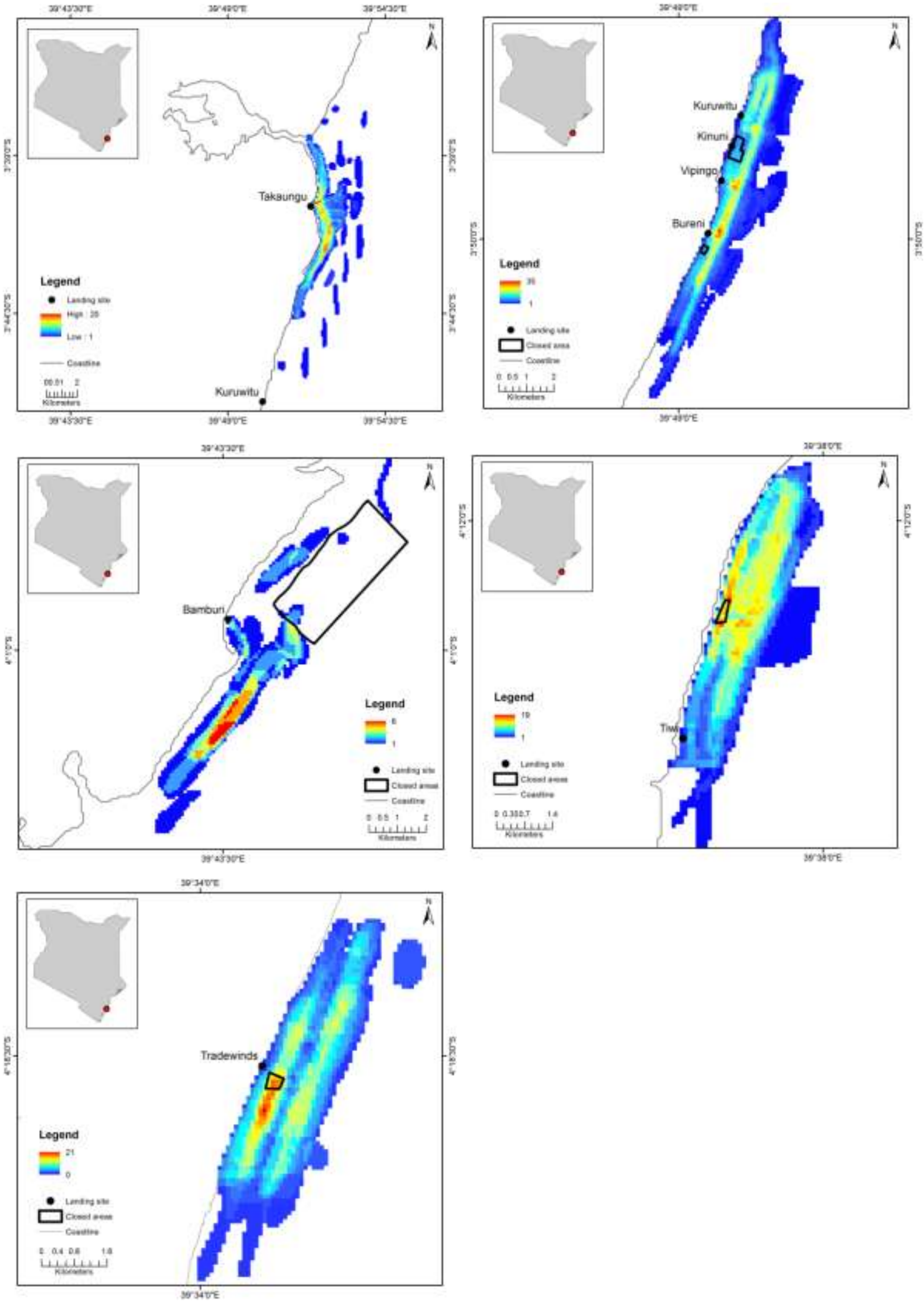
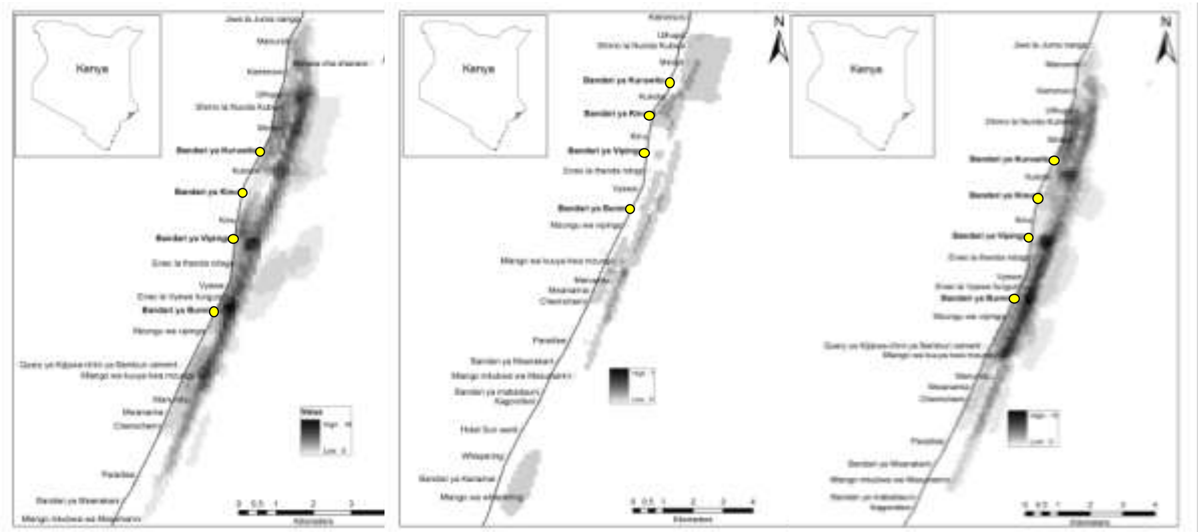


Figure 3.2. Aggregate fishing effort density according to surveymap data from each of the five Kenyan landing site areas. Each cell is coloured according to the number of fishers identifying it as a fishing ground.



Speargun (n=42) Hand line (n=7) Net (n=32)

Figure 3.3. Aggregate survey map data from 57 fishers from the highlighted four landing sites divided by fishing gear.

Effort patterns were similar for handline, speargun and net and all showed some concentration near the landing sites where interviews were conducted (suggesting very limited mobility of some fishers). There is some evidence for higher density for all three gears on a ground just north from Kuruwitu. Although fishers indicated they did not travel far offshore, fishing was indicated at distances of over 5km from the most northerly or southerly landing site, showing that some fishers travel more considerable distances along shore and probably overlap with fishers from other sites.

3.2. Fishing effort distribution from GPS monitoring

The detailed GPS monitoring data showed a similar general picture of resource space accessed from the 5 landing site areas as the surveymap method, but allowed the collection of detailed relative frequency of use by individual fishers.

Table 3.1 Numbers of trips monitored by GPS from each landing site.

LandSite	Number of trips with complete GPS data	Number of fishers
Takaungu	390	10
Kuruwitu area	*291*	*11*
- Kinuni	32	2
- Kuruwitu	174	4
- Vipingo	7	1
- Bureni	78	4
Bamburi	36	1
Tiwi	51	3
Tradewinds	51	4

This data is summarised in Figure 3.4 averaged for all fishers monitored at each landingsite area. Hi proportions of time were spent within the nearshore areas within a short distance of the landing site. In the Kuruwitu area, most trips were over the reef apart from a single sail vessel which spread effort over a much wider area extending to ~6km offshore. In Takaungu, although highest concentrations also occurred next to the landing site, fishing activity spread over a wider area (~15km) overlapping with Kuruwitu landing sites in the south.

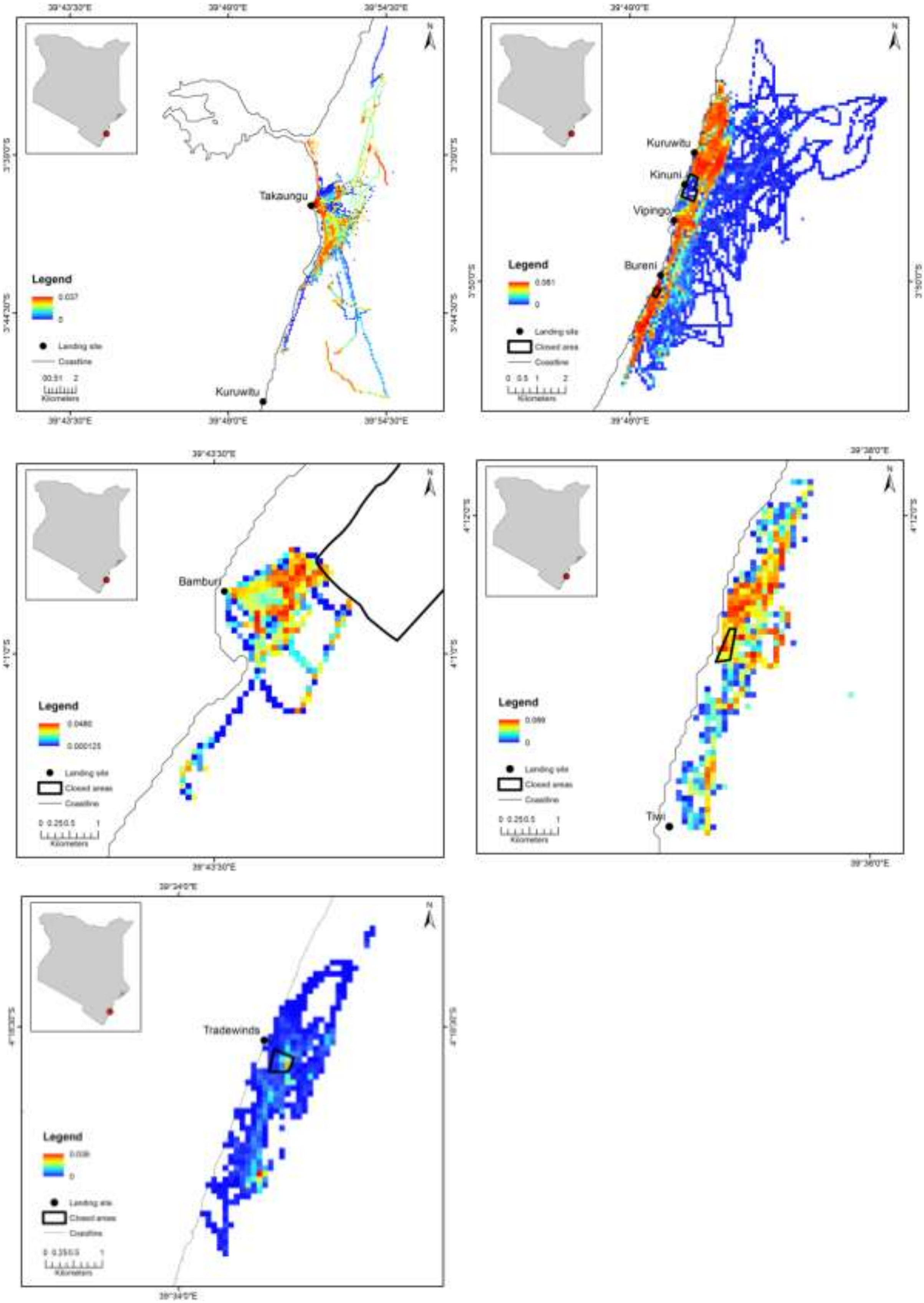


Figure 3.4. Fishing effort density from GPS monitoring. Cells are coloured according to the proportion of monitored time spent in each cell, averaged across all monitored fishers.

3.3. Distance from shore travelled by Kenyan fishers according to GPS monitoring

GPS monitoring allowed examination of detailed and accurate spatial behaviour of a limited number of fishers over a limited number of trips. All points from GPS tracks were spatially joined to a 25m grid which was in turn characterised by the distance to shore of the centroid of each grid cell. This allowed a straightforward calculation of the maximum distance from shore of each trip, which was then related to trip details according to associated logbook data.

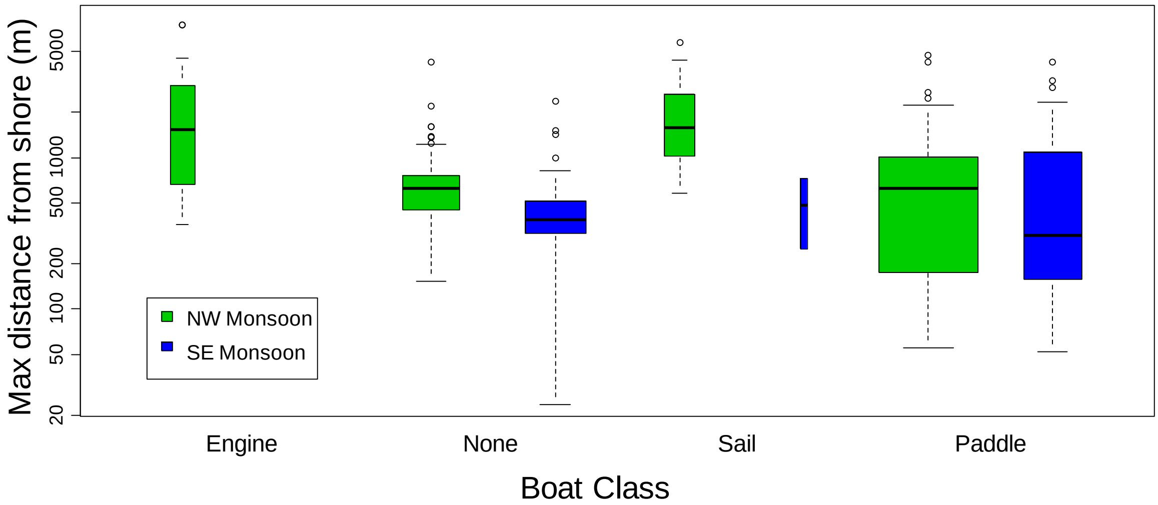


Figure 3.5. Maximum distance of Kenyan fishing trips from shore arranged by boat type and season. Note logarithmic scale on the y axis. Width of boxes indicates relative sample size for each type of trip.

Both season (ANOVA test, $F = 31.9$, $p<0.001$) and vessel type (ANOVA test, $F = 28.8$, $p<0.001$) had significant effects on maximum distance from shore (Figure 3.5). Trips in the southeast monsoon were on average 26% closer to shore than in the northwest monsoon. Trips by fishers without a vessel were closer to shore than small paddle boats (Tukey honest significance test, $p=0.10$), which were closer to shore than engine powered boats (Tukey HST, $p=0$) and sailboats. There was no significant difference in maximum distance offshore by engine and sailboat trips. However these results are preliminary due to the limited sample size of trips by sail and engine powered vessels (35 and 21 trips respectively) compared to the sample of non-boat and small, paddled boat trips (245 and 462 trips).

Chapter 4. How do fishers decide where to fish?

Fishers spatial behaviour is a result of individual decisionmaking processes, based on a range of possible factors. We asked fishers in both qualitative interviews and discussions and in a structured survey about the factors that affect their short-term (i.e. day to day) decisions about where to fish. The survey included an open ended question on decisionmaking factors, which was followed up by probes about specific factors that had not been volunteered, but had been highlighted in earlier exploratory qualitative interviews with expert fishers and groups. This allowed each factor to be either volunteered by the fisher, agreed with when prompted or disagreed with (i.e. the fisher would state that this factor did not affect decisions) (Figure 4.1). Fishers then also asked which was the most significant factor (Figure 4.2).

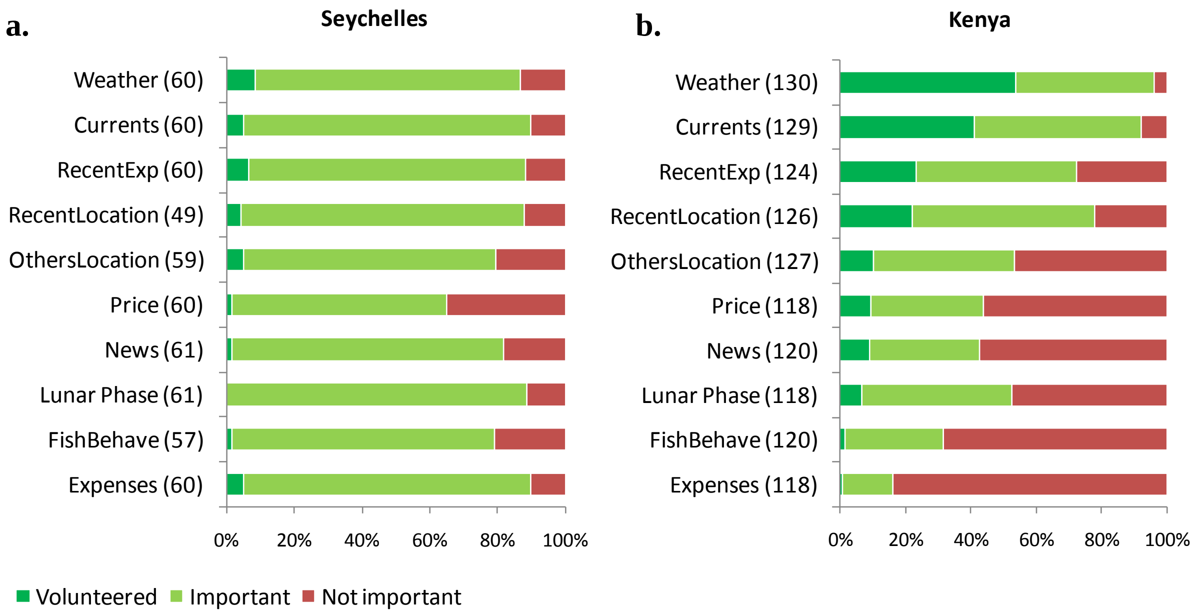


Figure 4.1. Factors considered by fishers when making decision about where to go fishing.
(Weather = Weather and sea state; Currents = Currents; RecentExp = Your experience of recent catches (e.g. big or poor catches); RecentLocation = Where you have fished recently (e.g. not fished there in a while); OthersLocation = Where other fishers are fishing; Price = Price of fish; News = News from other fishers; Lunar Phase = Lunar Phase; FishBehave = What you think the fish are doing (e.g. aggregations, catchability); Expenses = Fishing expenses (e.g. fuel, bait))

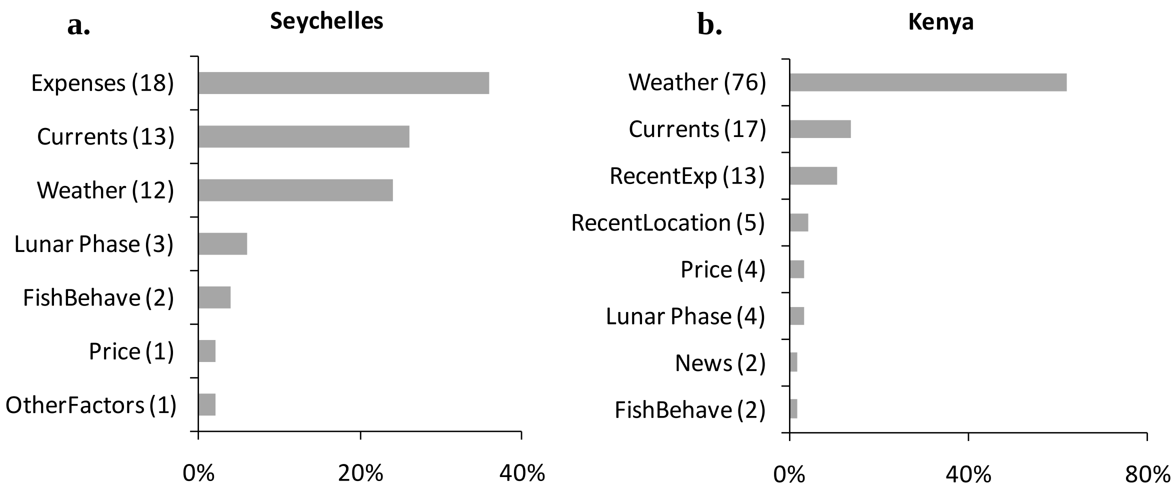


Figure 4.2. Most important factor considered by fishers when making decision about where to go fishing

In Seychelles, all factors are considered by fishers to decide where to go fishing (Fig. 4.1a). The most important factors were expenses, currents and weather (Fig. 4.2a). In Kenya, there were a variety of responses for each factor (Fig. 4.1b). The most important factors were weather, currents and recent experience (Fig. 4.2b).

4.1. Weather and sea conditions

In both Seychelles and Kenya, fishers consider the weather and the currents when deciding on where to go fishing. If it is rough, there is no fishing or they will fish inshore. If it is calm, they considered they will catch more fish.
Most fishermen seem to use their own knowledge of the weather and sea conditions when deciding where to go. "With the experience I've gathered throughout the years, I know a few places where there are fish with different types of weather or sea conditions……I decide when we get to the shore. I check the sea condition and then decide where to go" (SC KI 04 090708). "I observe the wind direction. For example now at present it will be difficult to fish around Mammelles, it's a problem, but it's a pity because that's where we get most fish, so we have to go there even if it's rough" (SC KI 02 090615). The weather influences their ability to see landmarks which they use to navigate the fishing grounds (SC KI 04 090708, SC KI 05 090710). In Kenya, when asked why when is the right day to go fishing he said "the sky should be clear of clouds or not foggy to allow easy navigation to fishing area which is far beyond Outer reefs (KePoKI 090521).

4.2. Familiarity with grounds

In both Seychelles and Kenya, fishers visit the same place frequently and go back to the same place after good catch.
It is noted in KE FG Kur 090509 and KE FG Wat 090710 that most fishers continue fishing places that they were introduced to by their parents or mentors, and those using the same gear type but once they become 'experts' they venture to other areas. Familiarity with site navigation and knowledge of fish abundance of target fish species seems to be also a key factor driving the location choice. Ke PO 090521 reveals that most fishers using outrigger are said to go fishing in Sale sale and Benko fishing grounds as they know to navigate to the sites and sites are known to have more fish and larger ones. KEPO 090615 said "the area is very deep and has large reef rocks(swahili termed as karasho or mawe mawe) that attract fish for hiding". This shows that fishers choose their fishing location as they have knowledge of the bottom habitat. KE FG Tak 090404 reveals that age is a great source of information because we learn from older fishers using the same gear. A lot of information was also sourced from fore fathers who associated place of fishing with gear. SC KI 01 090324 also says he learned where to fish from his mentor.

Lunar phase is considered a factor in both countries, but it seems that the importance of lunar phase is different. In Seychelles, fishers consider the lunar phase mainly to target specific species. However in Kenya, fishers consider the lunar phase for the roughness and the darkness of tides.

In Seychelles, fuel is the most talked about expense. Many fishers mention how the rising fuel price somewhat limits where they fish these days. They take the cost of fuel into account when deciding where to fish "Definitely, or else I would not be able to come back if I run out of fuel" (SC KI 02 090615). Interviews with fishers in Seychelles, where motorised vessels

are the norm, emphasised the role of fuel costs in constraining both fishing activities and exploration of new fishing grounds, illustrated by the following quote: *"…there are a lot of places that I used to go but I don't go anymore because fuel costs are too high*".
In Kenya, expenses are not really considered because there is often no expense for them. Most fishers use simple dugout canoes that are propelled using poles to fishing grounds and make decision on where to fish depending on the number of crew to expedite their energy to fishing activity.

In Seychelles, other factors considered include gear type and bait type. In Kenya, other factors considered include gear type, specific orders and distance.

4.3. Sources and sharing of information

In Seychelles, fishers consider the news from other fishers as reliable and would mainly use those news for specific species. In Kenya, fishers consider the news from other fishers differently depending on if they think the news are reliable or not.
In Kenya, locations of where other fishers are fishing are considered for competition, if there are other fishers, there is competition.
The Kenyan fishermen seem to share information more readily than the fishermen in the Seychelles (Fig. 4.3.). There is a sense of reciprocity in Kenya where it is felt that if you share your information you will be returned the favour or thanked in some way in return (KE FG Tak 090512). The information is shared during social gatherings or happy hour (coffee time) (KE FG Tak 090404, KE FG Tak 090512). However, even if information is not shared the fishermen claim to be able to detect the area from where the fish have come. It is noted in KE FG Tak 090404 that - Sharing of information is a must and if one is reluctant to do so, the catch itself will report you "Samaki itakusema".
However, in the more offshore fishery of Watamu, sharing information is less common although the fishermen have a vague idea of where other fishermen are fishing as many of them head out together and part ways out at sea (KE FG Wat 090710). This focus group also mentioned that fishermen want to guard productive fishing grounds for themselves and will even give misleading information to inexperienced fishers. "A fisher always wants to get more for himself" (KE FG Wat 090710).

In the Seychelles information about Carangue is shared to a greater degree than information on other species as "it's easier to fish them [Carangue] when there are a few boats together" (SC KI 04 090708). SC KI 01090324 says that even this information about Carangue is only shared with a select few who are close to each other. SC KI 03 090708 on the other hand mentions that getting information about Carangue is relatively simple. "at night you check with the other fishermen which one caught Carangue so you follow them" (SC KI 03 090708). Information about other species is more difficult to acquire and many fishermen don't trust the information others give them about these sites. For example, SC KI 01 090324 and SC KI 07 090729 say that fishermen "will never tell" where there are bourgeois [red snapper]fish.
Information sharing tends to be more selective in the Seychelles, for example between fishers who work together or those who are very close; "I will tell the fishermen in my other boat where we caught fish or they will tell me because we're working together, but I will not tell just any other fisherman" (SC KI 04 090708). Sometime fishermen who have had a bad catch the previous day follow those who have had a good catch. In this case SC KI 03 090708 says he will "go elsewhere, or you hide so that they don't see where you're going".

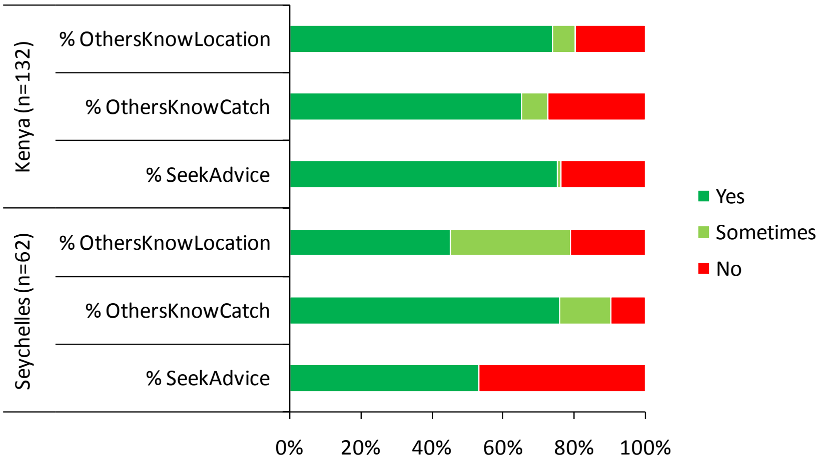


Figure 4.3. Communication with other fishers.
(OthersKnowLocation = Do other fishermen usually know where you went fishing?; OthersKnowCatch = Do other fishermen find out how much you caught while fishing?; SeekAdvice = Before you go to sea, do you usually seek advice from, or discuss with anyone, to help decide where to go fishing?)

Chapter 5. Displacement of fishing effort

A critical issue in the spatial behaviour of fishers is their capacity to adjust to changes in their fishing grounds. A number of changes to fishing grounds could displace fishers and cause them to adjust their spatial behaviour. These include: legislation (such as protected areas), habitat degradation (which makes certain places less viable as a fishing ground, and land reclamation projects (that can literally fill in fishing grounds with new land). We examined whether fishers in both Kenya and Seychelles had experienced displacement and how they have dealt with it.

Our surveys of 194 fishers revealed that the majority of respondents in both countries are fishing in the same general grounds that they were 10 years previously. However a considerable proportion of fishers (33% in Seychelles and 60% in Kenya) had been displaced, at least partially from their fishing grounds (Fig. 5.1a,b, 5.2a,b). These contrasting results could mean one of two things. First, fishers could be interpreting the question of whether they used to fish in the same areas quite broadly (i.e. they may still fish from the same landing site), but could be more specific about having been displaced from a smaller portion of their fishing ground by an MPA or reclamation project.

When fishers had been displaced, respondents from Seychelles tended to have three broad responses: they fished further out, found new grounds, or went deep sea fishing. In Kenya, when displaced, the majority of fishers (67%) said they found new grounds, but there was also a higher diversity of other responses not recorded in Seychelles, such as changing gear, or "doing nothing" (Fig. 5.3a,b).

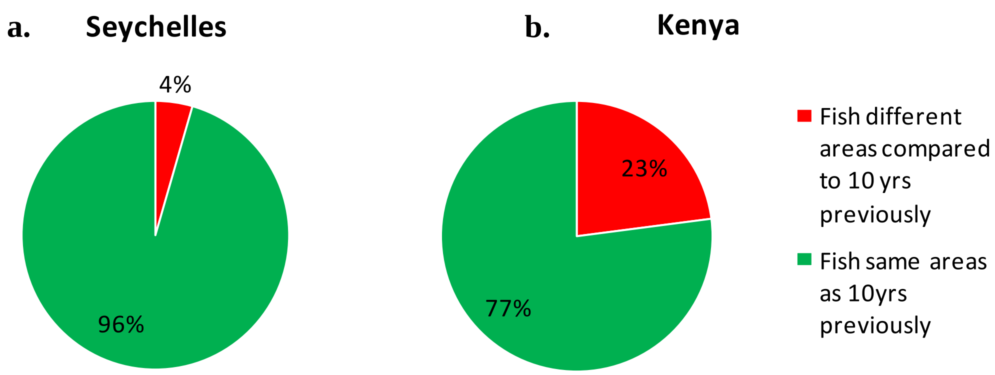
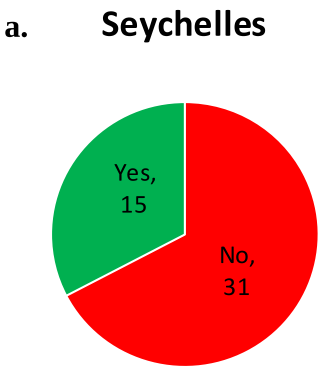


Figure 5.1. Answer to the question: "Did you used to fish in the area that is now the [displacement]?"



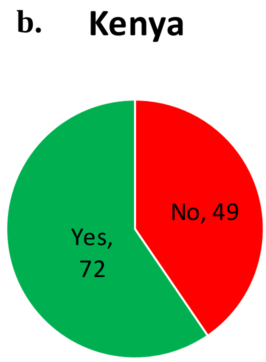
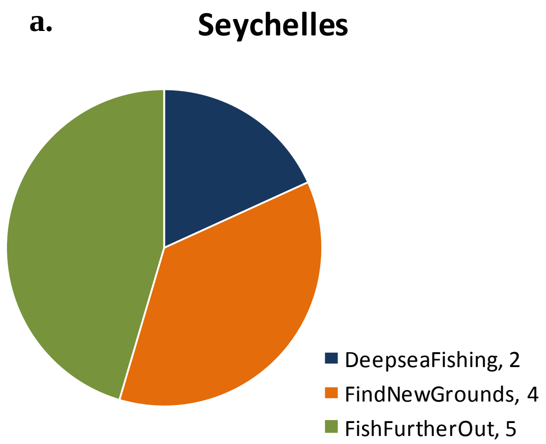


Figure 5.2. Answer to the question: "Did you used to fish in the area that is now the [displacement]?"



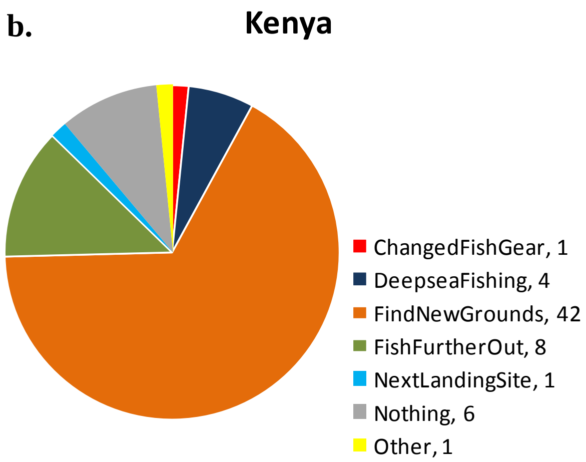


Figure 5.3. Answer to the question: "What did you do when you could no longer fish in [displacement area]?"
(Nothing = nothing; FishFurtherOut = Fish further out, go to next place nearby; FindNewGrounds = Find new fishing location; NextLandingSite = Moved to the next landing site; NeverDisplaced = Have not been displaced; DeepseaFishing = Do more deep sea fishing, i.e. outside the reef; ChangedFishGear = Change fishing gear; Other = Other response)

5.1. Explore new fishing areas

Since a high proportion of fishers mentioned finding new fishing grounds a sa mechanisms for dealing with displacement, we examined the ways that fishers in both countries explore new grounds. In the Seychelles 93% of fishers explore new areas, rather than in Kenya only 36% of fishers explore new areas (Fig. 5.4a,b). This is likely to be a result of the geography of the two countries. Seychelles has extremely large offshore banks with submerged features, many of which are unknown and unmapped. In contrast, the Kenyan coast that we studied is a lagoon system with well-defined boundaries approximately 1km from shore. Additionally, fishers in Kenya are much less likely to own or have access to a boat. These two conditions make exploring new areas in Kenya considerably more difficult.

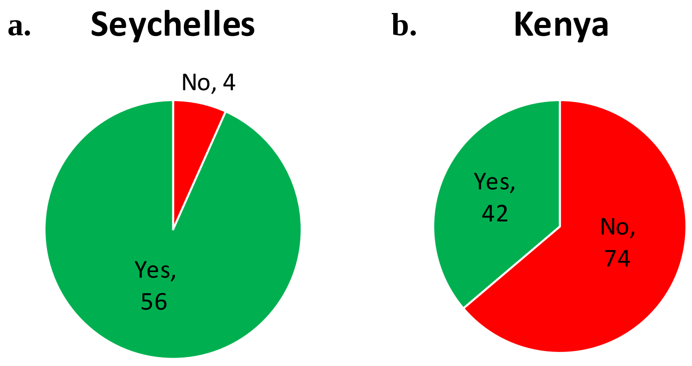


Figure 5.4. Answer to the question: "Do you ever explore new fishing areas that you haven't fished before?"

In the Seychelles, fishers have more specific techniques to explore new areas. Most use a technique locally called 'Sonde' which involves allowing the boat to drift with baited hooks in search of reefs or concentrations of fish. Echosounders are also used by some fishers when exploring new areas for fishing, or In Kenya, fishers explore new areas for fishing in more traditional ways: 47% do simple trial and error, 34% use fishers information and 16% ecological knowledge (Fig. 5.5a,b). In the Seychelles, the majority of fishers (74%) find new grounds while they are fishing. In Kenya however fishers look for new areas for specific reasons: 40% after poor catches and 23% seasonally, only 11% while fishing (Fig. 5.6a,b).

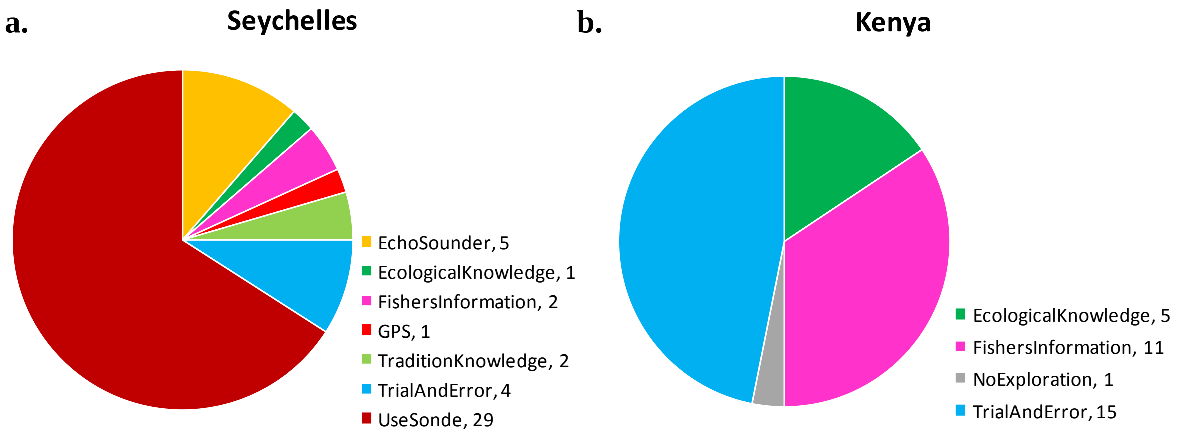


Figure 5.5. Answer to the question: "How do you do this?"
(FishersInformation = Go fishing to places where others go and that other fishers advise to go; UseSonde = Use sonde; GPS = Use GPS; TraditionKnowledge = Get advice from older fishermen or by experience; TrialAndError = Try and error method; EcologicalKnowledge = Know the ecology of fish and other organisms; NoExploration = Not really looking for a new fishing spot; EchoSounder = Use an echosounder)

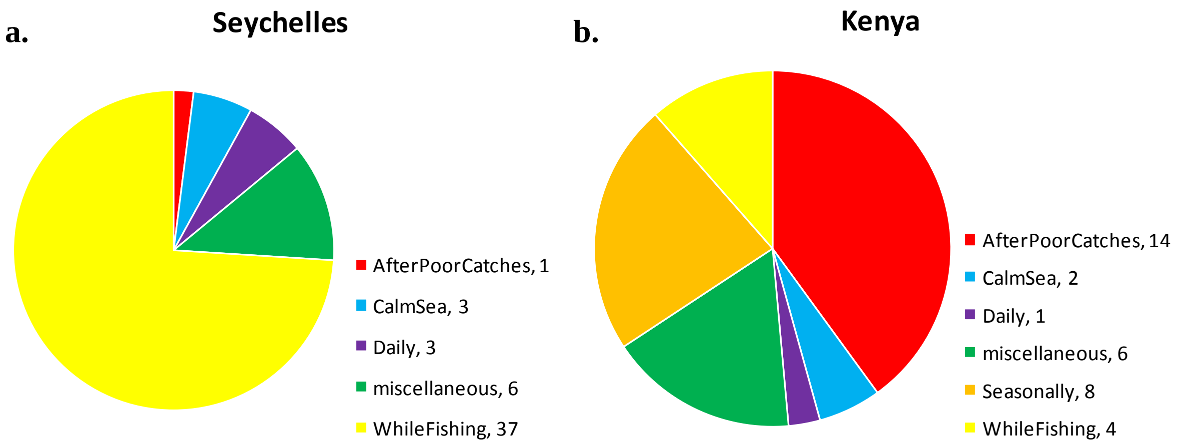


Figure 5.6. Answer to the question: "When would you explore rather than going to an area you already know?"
(AfterPoorCatches = Explore new fishing place after poor catches; CalmSea = Explore new fishing place when the sea is calm; Daily = Explore new fishing place everyday; miscellaneous = Explore new fishing place whenever; Seasonally = Explore new fishing place during special season; WhileFishing = Explore new fishing while fishing)

Chapter 6. Spillover

6.1. Introduction

The concept of spillover, the export of both larvae and adult fishes from marine reserves to outside areas, is implicitly or explicitly stated as a justification for the establishment of the majority of coral reef marine parks. For fish larvae, the broad concept is that fish are larger and more fecund inside marine reserves, which results in export of more, larger, and fitter eggs to outside areas. Fishers are generally more concerned with the export of adult fishes from reserves to outside areas. There are two broad mechanisms through which this is expected to happen. First, density-dependent interaction of fishes inside marine reserves is expected to “push” some adult fishes across the reserve boundary, making them available to fishers in adjacent fishing grounds. Secondly, is that when subjected to higher fishing pressure, fishes have been shown to exhibit behaviour that makes them more difficult to catch by gears such as spear guns (Feary, Cinner et al. 2011; Januchowski-Hartley, Graham et al. 2011). Inside marine reserves, target fishes have been shown to have lower flight initiation distance, which may make them more susceptible to fishing if they swim across the reserve boundary (Gotanda, Turgeon et al. 2009; Feary, Cinner et al. 2011; Januchowski-Hartley, Graham et al. 2011).

Adult spillover is hypothesized to increase profitability and yields for fishers, although empirical evidence for this is supportive, but controversial. Several studies have found that total catch or catch per unit effort (CPUE) for coral reef fishes is higher in areas adjacent to marine reserves compared with areas further away (McClanahan and Kaunda-Arara 1996; McClanahan and Mangi 2000; Russ, Alcala et al. 2003; Kaunda-Arara and Rose 2004; McClanahan, Hicks et al. 2008; McClanahan 2010). However, results vary by species and habitat and are often confounded by other management measures, such as banning destructive gears, that would be expected to increase fisheries yields (e.g., Galal, Hassan et al. 2002; Kaunda-Arara and Rose 2004; Russ, Alcala et al. 2004). For example, the establishment two of the best studies cases of marine reserve spillover (Apo Island in the Philippines and Mombasa Marine Park in Kenya) were accompanied by banning the use of explosives, poisons, muro ami (a destructive form of net fishing where corals are broken with rocks to scare fish into the net), or beach seine nets (Russ, Alcala et al. 2004). In Mombasa, catches in the trap fishery were higher close to the marine reserve on the side where beach seines were effectively excluded, but not on the side of the park where seine netting continued (although habitat differences may have been a factor) (McClanahan and Mangi 2000).

While a number of studies have examined the ecological and economic dimensions of spillover, few studies have explicitly examined the social dimensions of spillover- namely how fishers experience and perceive spillover from marine reserves. Here, we interviewed 132 fishers from Kenya and 62 fishers from Seychelles to explore their perceptions about and personal experience with spillover. Specifically, we examine: 1) whether people fish near MPAs; 2) whether they used to fish in areas displaced; 3) whether they have personally caught fish they thought spilled over from a reserve; 4) whether their catch has increased or decreased as a result of the reserve; 5) and whether they think it has been positive or negative for their livelihoods. In addition, we explore whether certain types of fishers are more likely to experience either benefits or costs of marine reserves by testing whether key socioeconomic characteristics (poverty, age, migration) are related to answers to the aforementioned questions.

6.2. Methods summary

Sampling

Quantitative and qualitative.
To provide additional information and richness, the quantitative surveys were also supported with more in-depth qualitative interviews (9) in Seychelles and focus groups (7) in Kenya.

Dependent variables
Fishers were asked: 1) whether people fish near MPAs (and the reasons why people fish there); 2) whether they personally used to fish in areas that have been displaced by either MPAs or coastal development; 3) whether they have personally caught fish they thought spilled over from a reserve; 4) whether their catch has increased or decreased as a result of the reserve; 5) and whether the marine reserve has been positive or negative for their livelihoods.

Independent variables
We examined 7 key socioeconomic characteristics of fishers: 1) whether they used a boat; 2) whether they were a migrant; 3) their age; 4) landing site (i.e. geographic location); 5) their bi-weekly expenses; 6) the gear types the fisher used [including handline, spear, trap, gillnet, trap, mixed (i.e. a combination of these), and other (i.e. octopus hook, seine net)]; and 7) a multivariate measure of material style of life based on the presence of their household possessions and structures (Pollnac and Crawford, 2000), which was factor analyzed to develop an index of wealth. The material style of life principal components in Kenya and Seychelles explained 35% and 22% of the variance, respectively (Table 6.1).

Table 6.1. Factor loadings of material style of life principal component analyses

Kenya		**Seychelles**	
Bicycle	0.18	Bicycle	-0.03
Motorcycle	0.04	Motorcycle	0.01
RoofThatch	-0.42	SmallCar	-0.11
RoofMetal	0.40	PickUpOrJeep	-0.16
RoofTile	0.00	Boat	0.09
FloorBamboo	-0.02	RoofMetal	-0.01
FloorCement	0.46	RoofTile	-0.01
FloorFinished	0.00	FloorWood	0.03
FloorDirtSoil	-0.49	FloorCement	-0.14
WallsBamboo	-0.07	FloorFinished	0.11
WallsWood	-0.01	WallsWood	0.07
WallsStone	0.20	WallsStone	0.42
WallsMetal	0.02	WallsMetal	0.15
WallsCement	0.17	WallsCement	-0.47
WallsCoral	0.00	WallsCoral	0.00
WallsMud	-0.24	WallsMud	0.00
VCR	0.10	VCR	-0.03
Cable	0.01	Cable	-0.38
AirCon	0.04	AirCon	-0.07
TV	0.17	Computer	-0.43
		Internet	-0.34
		HotWater	-0.22

Dishwasher	-0.05
TV	0.00
Freezer	-0.01

Analysis
To test whether fishers perceived experience with MPAs was related to their socioeconomic characteristics, we conducted three types of analyses. The Chi-squared test was used when both dependent and independent variables were nominal. The t-test was used when the independent variable was continuous and the dependent variable had two categories (e.g., to test whether the mean level of fortnightly expenditures was different for fishers who were displaced compared to those that were not displaced). The Kruskal-Wallis test was used when the independent variable was continuous and dependent variable had three categories (e.g., to test whether the mean level of fortnightly expenditures was different for fishers who perceived positive, negative, or neutral impacts on their livelihoods).

6.3. Results

Material Style of life

6.3.1. Do people fish near the MPA? What are the reasons?

In both the Seychelles and Kenya, the majority of fishers say that people go fishing near the MPA (Fig 6.1a,b). The main reason seems to be to get more fish, particularly in Kenya (Fig. 6.2b). However, “no reason” was provided as the second most frequent reason in both countries. Because such a high proportion of fishers noted that people fish near marine reserves, it was not sensible to look for differences in the six socioeconomic characteristics between fishers with different responses to this question.

Qualitative interviews with fishers in Seychelles yielded contrasting results; few of our qualitative respondents claimed to regularly fish the MPA boundary, suggesting that they only fished near marine parks when weather was bad (where MPAs are located near shore) or when they actually intended to poach in the closure. These respondents did not describe fishing near the boundary to increase catch. By contrast, a Kenyan focus group near the Kuruwitu community-based MPA agreed that they fish close to the park. The overall view of that focus group was that parks improve catch through spill over despite the displacement. Differences between Seychelles and Kenya may be partly related to the differences in MPA configuration, geomorphology and fishery characteristics, whereby in Seychelles MPAs tend to enclose reefs next shore, with limited contiguous fishing habitat, and fishers have the capacity to travel much further. In Kenya MPAs are imposed along a linear arrangement of contiguous habitat and fishers are constrained by access to vessels.

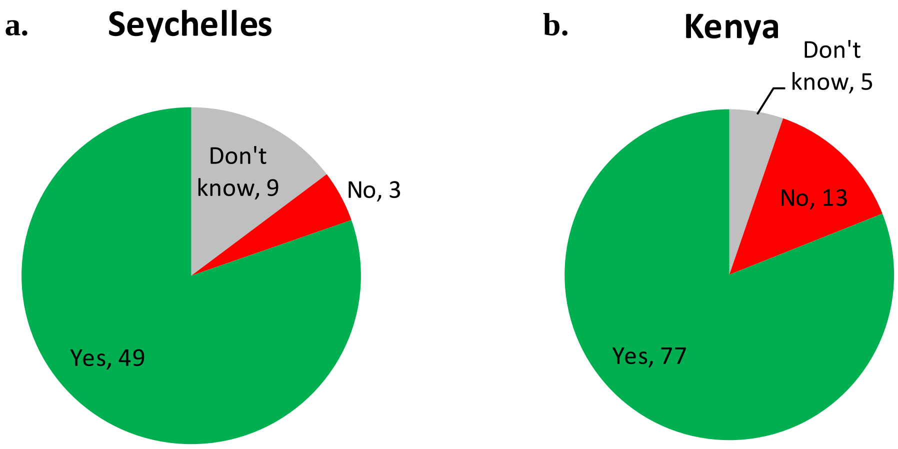


Figure 6.1. Answer to the questions: "Do any fishermen fish close to (but outside) the boundary of the closure?"

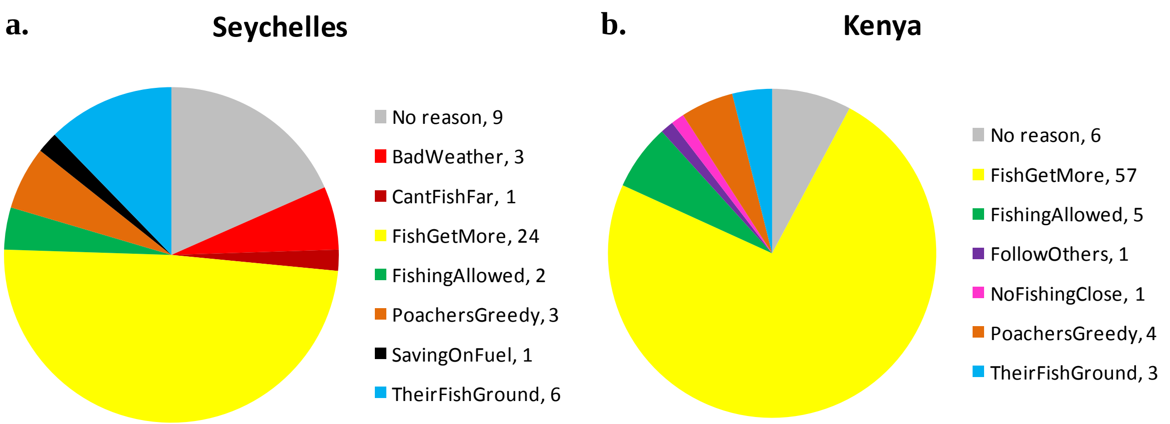
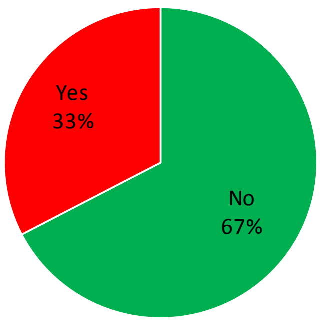


Figure 6.2. Answer to the questions: "Why do fishermen fish close to (but outside) the boundary of the closure?"
(BadWeather = because of bad weather; CantFishFar = Can't go very far out to fish; DontKnow = Don't know; FishGetMore = Get more fish; FishingAllowed = Fishing is allowed outside; FishThatGetOut = Get the fish that get out; FollowOthers = Fish like other fishers; NoFishingClose = Don't fish close to boundary; NotIdicated = no reponse; PoachersGreedy = They fish in closure; SavingOnFuel = To save on fuel; TheirFishGround = It is their fishing ground)

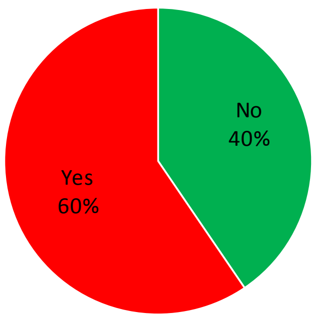
6.3.2. Did fishers used to fish in the displacement area?

In the Seychelles, one third (33%) of respondents had been displaced by a local closure or displacement (Fig 6.3a) and there are significant differences between regions where more fishers in East and West Mahe seem to have been displaced than in North East and South West Praslin (Fig 6.3c; $Chi^2(3, n=46) = 9.6$, $p = 0.02$). In Kenya, two thirds (60%) of the fishers we interviewed had been displaced Fig (6.3b). Again, there were significant differences between regions (Fig 6.3d; $Chi^2(7, n=121) = 48.9$, $p < 0.0001$). Additionally, fishers who use a boat were less displaced than fishers that do not use a boat (Fig 6.3f; $Chi^2(1, n=119) = 5.4$, $p = 0.02$). Although there appeared to be differences in displacement among the different gear types, these were not statistically significant (Fig 6.3g,h). In Kenya, fishers that were displaced also had significantly lower fortnightly expenditures and a lower material style of life (Table 6.1). In Seychelles, socioeconomic characteristics were not significantly different between fishers that were displaced or not.

a. Seychelles



b. Kenya



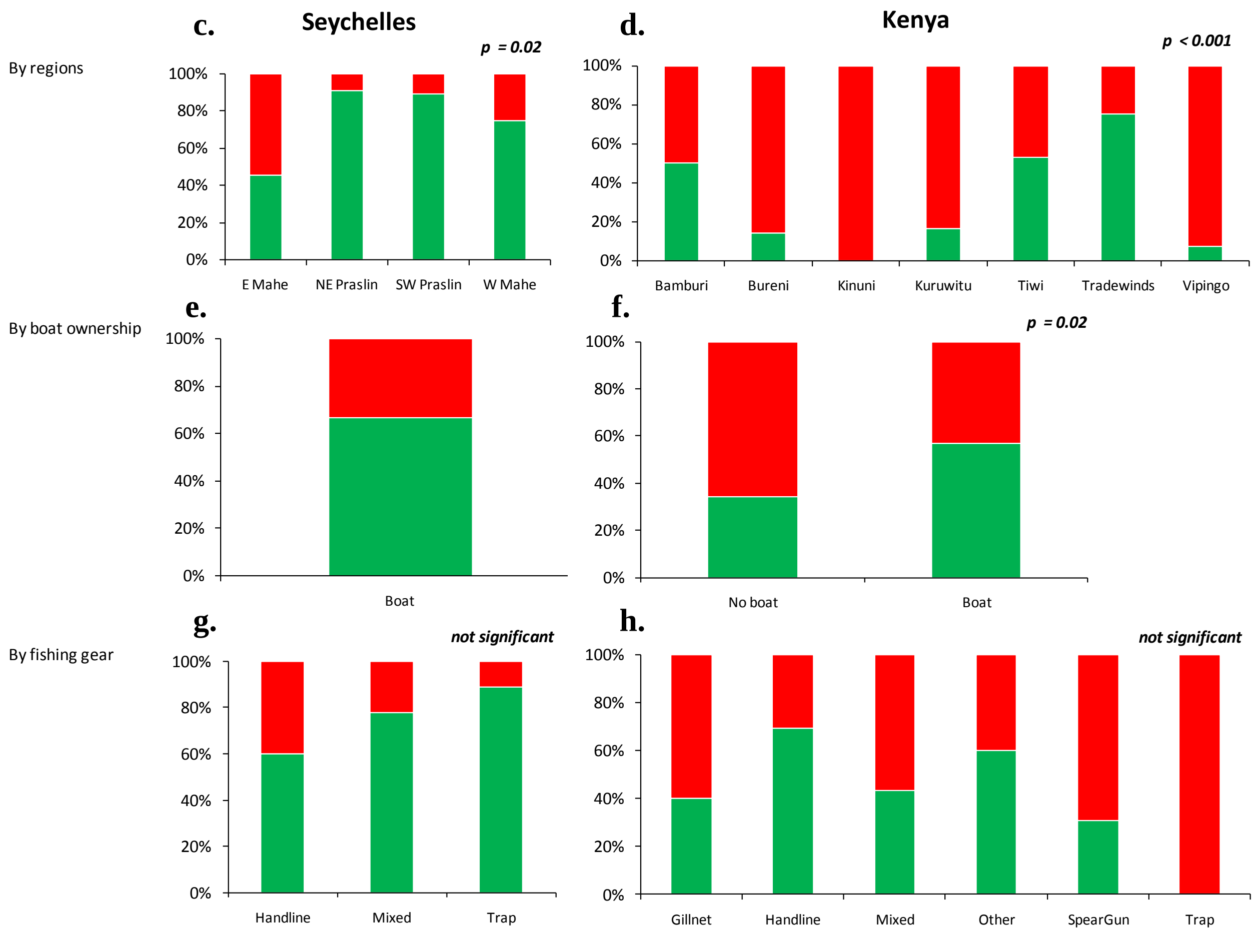


Figure 6.3. Answer to the question "Did you use to fish in the displacement area?"

Table 6.2. Mean levels of fortnightly expenditures and material style of life for fishers that were displaced compared to those that were not.

	Fishers displaced	Fishers not displaced	F	p
Material style of life index	-0.173 ± 0.098	0.289 ± 0.133	8.039	0.005
Fortnightly expenditure (USD)	100 ± 6.1	127 ± 10.1	5.988	0.016

6.3.3. *Do fishers feel that they catch fish that spilled over from the closure?*

In both the Seychelles and Kenya, 90% of fishers felt that they have personally caught fish that spilled over from marine reserves (Fig. 6.4a,b). Due to the low heterogeneity in responses, comparisons between the socioeconomic characteristics of fishers with different perceptions about spillover were not sensible.

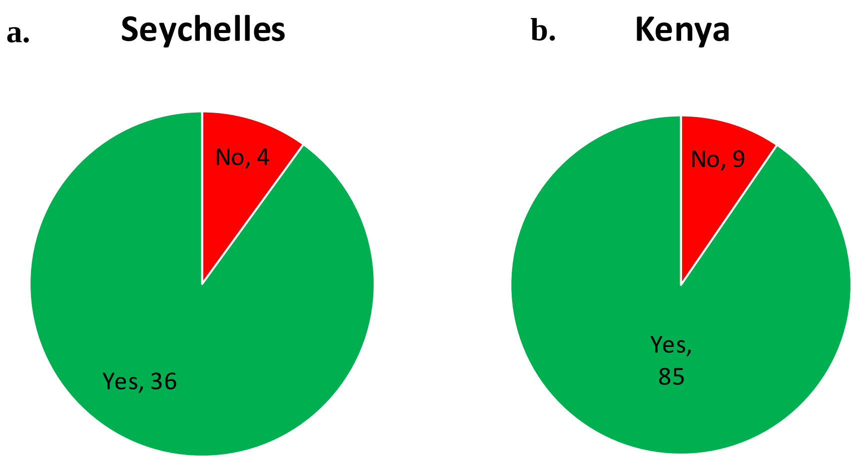
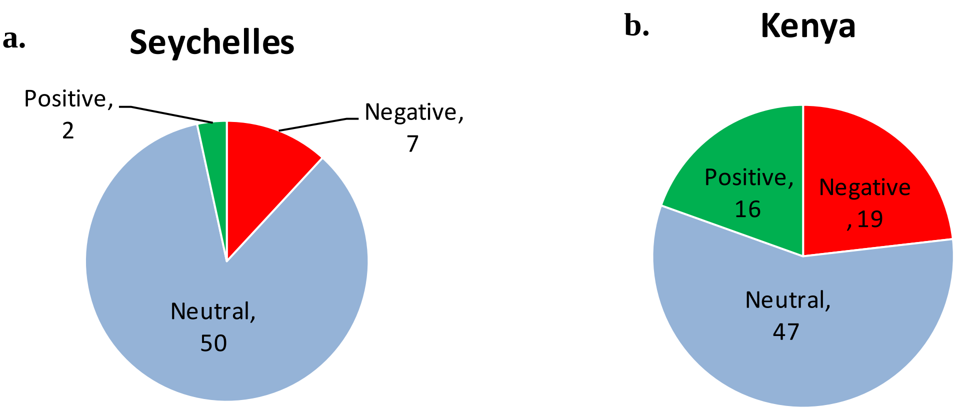


Figure 6.4. Answer to the question "Do you think that you catch fish that swim out of the closure?"

6.3.4. *What is the perceived impact of the closure on fishers' catch?*

In the Seychelles, the vast majority of fishers perceived a neutral effect of marine reserves on their catch (Fig. 6.5a). In Kenya, a smaller majority of fishers (57%) also perceived a neutral effect, 23% felt like their catches declined, and 20% felt like their catches increased as a result of the marine reserve (Fig. 6.5b). In Kenya, there are significant differences between regions, with Kuruwitu and Kinuni (both landing sites adjacent to the Kuruwitu conservation area) reporting the most negative impacts, but Vipingo (also adjacent to the same closure) reporting the most positive effects (Fig 6.5d, $Chi^2(12, n=82) = 29.5$, $p = 0.003$). Apparent differences between gears (e.g. no handline fishers in Seychelles experienced increased catch) were not significant in either country (Fig 6.5e,f). Likewise, using a boat made no difference to the perceived impact of a closure on fishers catch (Fig 6.5g & h). In Kenya, fishers who felt that they benefited from the closure for their catch had a significantly lower fortnightly expenditure (75.3 ± 6.7 USD) than fishers who perceived a neutral (117.8 ± 8.9 USD) or a negative impact (109.8 ± 17.4 USD) [$F(2, 77) = 3.05$, $p = 0.053$]. In Seychelles, socioeconomic characteristics were not significantly different between fishers with different perceptions about the impacts of marine reserves on their catch.



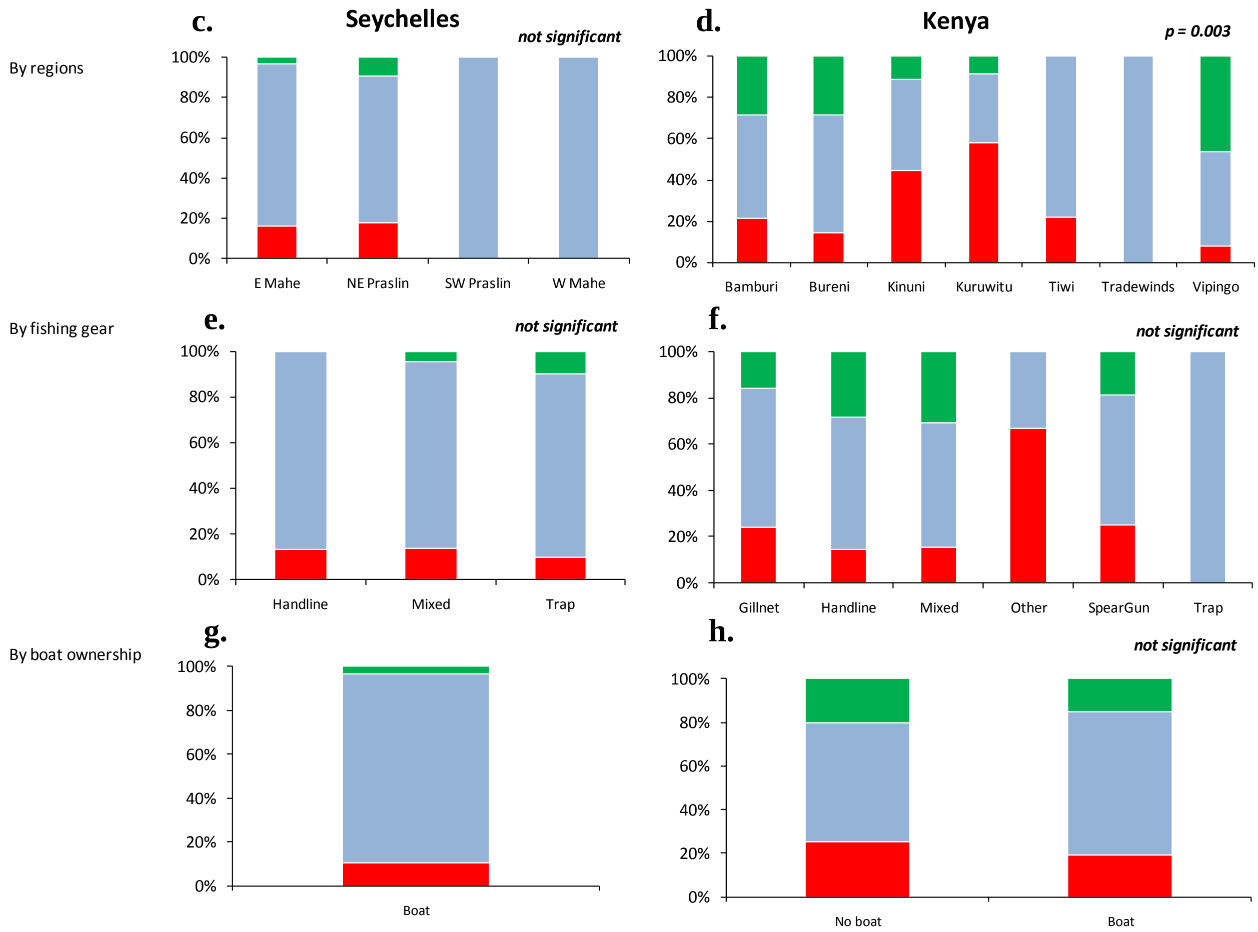


Figure 6.5. Answer to the question "How does the closure affect your catch as a fisherman?"

6.3.5. *What is the perceived impact of the closure on fishers' livelihood?*

In Seychelles, 75% of fishers felt that MPAs were positive for their livelihood, and this did not vary significantly by location or gear type (Fig 6.6 a,c,e). In Kenya, 45% felt that MPAs had a neutral impact on their livelihood, 35% felt a negative impact and 19% felt a positive impact. There were significant differences between regions in Kenya, with Bamburi (the landing site from the oldest and most well-enforced park we studied; Mombasa Marine Park) having extremely negative overall views about the parks impact on their livelihood, while Vipingo had the highest (Fig. 6.6d, $Chi^2(14, n=93) = 65.3$, $p < 0.0001$). There were also significant differences in the ways that boat users and non-boat users perceived impacts on their livelihoods. Interestingly, those without a boat were more likely to perceive a positive impact on their livelihoods, despite the result reported earlier that they were more likely to be displaced (Fig. 6.6h, $Chi^2(2, n=91) = 6.1$, $p = 0.048$). Fishing gear, boat type, or other socioeconomic characteristics were not significantly different between fishers with different perceptions about the impacts of marine reserves on their livelihoods.

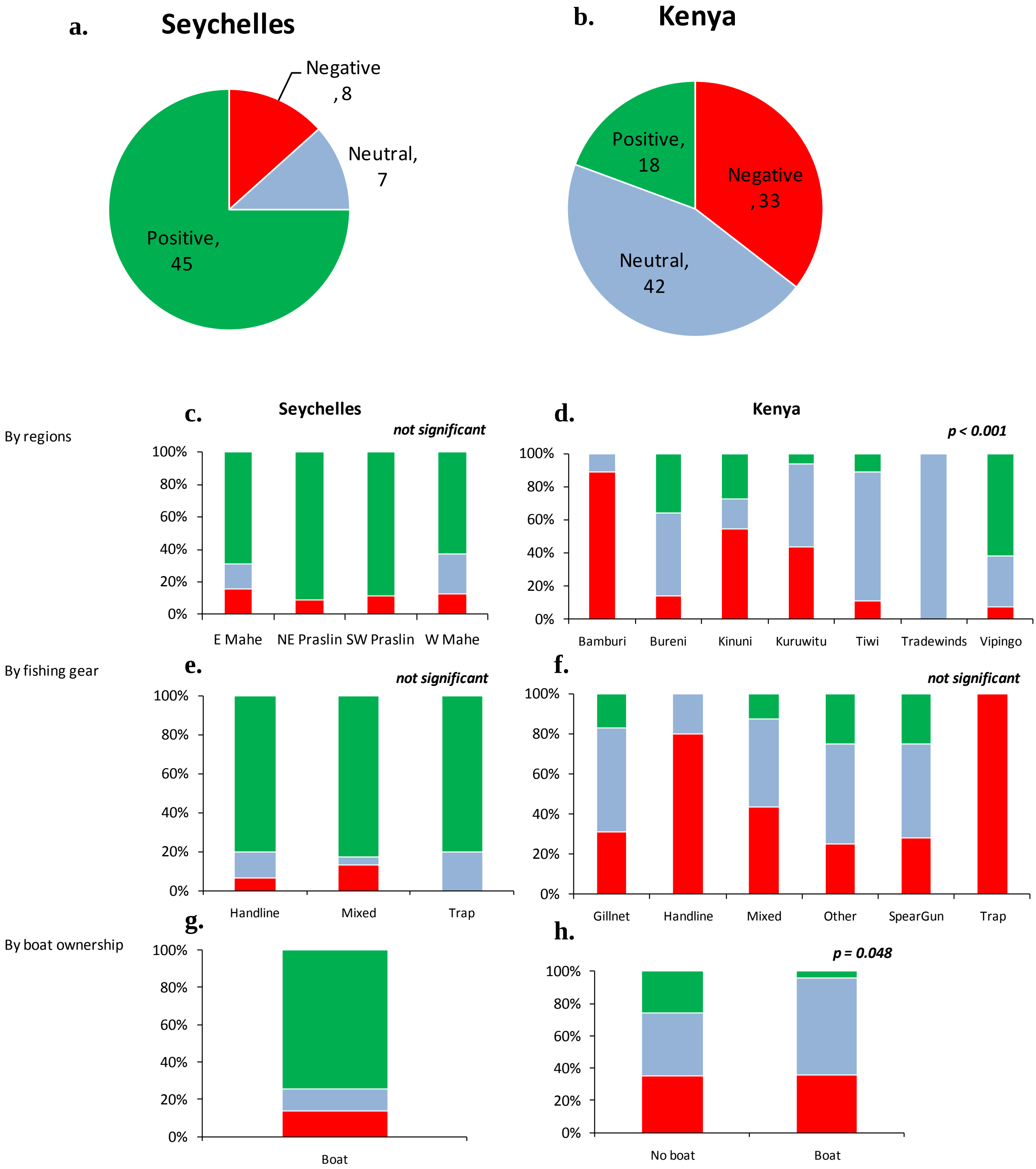


Figure 6.6. Answer to the question "Overall, how does the closure affect your livelihood?"

6.4. Discussion

This is one of the first studies to examined coral reef fishers' own perceptions about their experiences with spillover from marine reserves. Specifically, we looked at how over 194 fishers from two different countries perceive their experiences with protected areas and whether these perceptions are related to geographical and socioeconomic conditions. A key finding is that although adult spillover has been difficult to conclusively prove in the ecological and conservation literature, the vast majority of fishers in both Kenya and Seychelles claim to have experienced it. However, these fishers generally don't perceive that this leads to overall improvements in their catch.

Many of the studies to date which have explored the economic impacts of closures on fishers have not tended to look at distributional impacts, instead analyzing average levels of catch and/or profit for the entire landing site (Russ, Alcala et al. 2004; McClanahan 2010). However, social scientists have raised concerns that marine reserves can further entrench existing inequalities by benefiting the wealthy at the expense of the poor, in what is often referred to as 'elite capture' (Christie 2004). We found that, in Kenya, fishers' wealth was related to whether they were displaced from reserves and also whether they perceived an improvement in their catch. Interestingly, fishers with lower fortnightly expenditures and lower material style of life were more likely to be displaced, but critically, fishers with lower fortnightly expenditures were also more likely to perceive a positive effect on their catch. This might suggest that poorer fishers have a more limited range and are thus more likely to perceive both the negative and positive impacts of a closure. Critically, though, this relationship did not hold up in Seychelles and wealth was not related to overall perception of whether reserves in Kenya were beneficial or detrimental to fishers' livelihoods.

In Seychelles, despite considerable displacement (33%) and a distinct lack of perceived improvements to catch as a result of closures, the vast majority (75%) of fishers perceived closures as having a positive impact on their livelihood. In contrast, in Kenya, many fishers perceived an overall negative impact on both catch and their livelihoods. This suggests that although fishers are aware of, and claim to experience the potential benefits of marine reserves, they generally do not feel that these outweigh the other social and economic costs. However, at least in Kenya, the heterogeneity in these overall experiences were significantly related to both geography (specifically, which landing site the fisher was from) and whether fishers used a boat.

Ironically, one of the few places globally were spillover has had a demonstrable impact on fishers' catch and profitability (the Bamburi landing site adjacent to the Mombasa marine park), is where overall experiences with the park were most negative. One potential explanation for this is that Bamburi was adjacent to the only government closure we studied (the others were small, community-based closured locally referred to as *tengefu*). The national park versus community-based status has implications for whether and how rents from tourism visits are distributed (in a national park, all revenue goes to central government coffers whereas locally managed MPAs can distribute tourism visitation fees to community members). Thus, these negative perceptions about the Mombasa marine park by fishers could be viewed as a consequence of fishers not feeling like they benefit from the alternative activities occurring in the reserves. However, Kuruwitu, which has the oldest and arguably most successful tengefu, with a fee structure in place for visiting tourists, also had largely negative perceptions about the overall impact of the closure on fishers' livelihoods.

Chapter 7. Project Conclusions and Outputs

The ways that fishers use their resource space is complex and strongly influenced by a range of technological, geographical, social, and economic issues. These complexities, and the difficulties in researching them, have led many scientists and managers to make poor assumptions about the costs and benefits of policies such as marine reserves. We developed a participatory methodology for exploring spatial dimensions of resource use in artisanal reef fisheries. Five key lessons emerged from this project:

- Although fishers perceive spillover from marine reserves, this does not necessarily translate to perceived improvements in catch.
- There are under-recognized distributional inequalities in who marine reserves affect. In particular, it is poorer fishers in Kenya that were both displaced from, and also felt like they benefited from marine reserves.
- The resource space of individual fishers, is determined by vessel type and season. In particular, in Kenya, effort is focussed on the fringing reef with fewer, larger sail and motorised vessels travelling any distance beyond the fringing reef.
- Although our interdisciplinary and participatory methods for examining spatial behaviour yielded some key findings, there are critical data issues that need to be taken into consideration in future projects. Specifically, the complexity of storing, managing and in particular, analysing such data is easily underestimated. Various technical issues such as loss of signal, weak batteries or equipment malfunction can corrupt collected data. As such, regular plotting of collected data in GIS overlaid on satellite imagery is essential for early identification of problems.

Outputs

Data from this project has been presented at several forums to date, including:

- Daw et al. (2011) Fisher behaviour and displacement by MPAs. Oral Presentation at *WIOMSA/ReCoMaP MPAs & Fisheries symposium, Session 1: Ecological and Fisheries Effects* 14th March 2011, Mombasa.

- Daw et al (2011) Spatial decision-making by artisanal fishers in Seychelles and Kenya. Oral Presentation at *WIOMSA 7th International Symposium* 27th October 2011, Mombasa.

- Thoya et al (2011) Displacement of fishing effort from fisheries closures in Kenya and Seychelles: Winners, losers and responses. Oral Presentation at *WIOMSA 7th International Symposium* 27th October 2011, Mombasa.

- Thoya et al (2011) Use Of Hand Held Gps to Monitor Artisanal Fishermen. Poster Presentation at *WIOMSA 7th International Symposium* 24-28th October 2011, Mombasa.

References

Abernethy, K. E. (2010). Fishing for what? Understanding fisher decision-making in southwest England. School of International Development. Norwich, University of East Anglia. **PhD:** 271.

Abernethy, K. E., E. H. Allison, et al. (2007). "Why do fishers fish where they fish? Using the ideal free distribution to understand the behaviour of artisanal reef fishers." Canadian Journal of Fisheries and Aquatic Sciences **64**(11): 1595-1604.

Abernethy, K. E., P. Trebilcock, et al. (2010). "Fuelling the decline of UK fishing communities?" ICES Journal of Marine Science **[Advanced electronic access published January 8, 2010]**.

Abrahams, M. V. and M. C. Healey (1990). "Variation in the Competitive Abilities of Fishermen and Its Influence on the Spatial-Distribution of the British-Columbia Salmon Troll Fleet." Canadian Journal of Fisheries and Aquatic Sciences **47**(6): 1116-1121.

Aburto, J., M. Thiel, et al. (2009). "Allocation of effort in artisanal fisheries: the importance of migration and temporary fishing camps." Ocean and Coastal Management **52**: 646-654.

Acheson, J. M. (1975). "The Lobster Fiefs: Economic and ecological effects of territoriality in the Maine Lobster Industry." Human Ecology **39**(3): 183-207.

Acheson, J. M. (1981). "Anthropology of Fishing." Annual Review of Anthropology **10**: 275-316.

Adams, V. M., M. Mills, et al. (2010). Marine opportunity costs: a method for calculating opportunity costs to multiple stakeholder groups. Wildlife Conservation Society - Fiji Technical Report no. 01/10. Suva, Fiji, 34pp.

Alam, M. F., I. H. Omar, et al. (1996). "Sustainable resoource use, economic development and public regulation: the multiproduct gill net fishery of peninsular Malaysia." Environmental and Resource Economics **7**: 117-132.

Allen, P. M. and J. M. McGlade (1986). "Dynamics of Discovery and Exploitation - the Case of the Scotian Shelf Groundfish Fisheries." Canadian Journal of Fisheries and Aquatic Sciences **43**(6): 1187-1200.

Allison, E. H. and F. Ellis (2001). "The livelihoods approach and management of small-scale fisheries." Marine Policy **25**: 377-388.

Aswani, S. (1998). "Patterns of marine harvest effort in southwestern New Georgia, Soloman Islands: resource management or optimal foraging?" Ocean and Coastal Management **40**: 207-235.

Babcock, R. C., N. T. Shears, et al. (2010). "Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects." Proceedings of the National Academy of Sciences **107**(43): 18256-18261.

Begossi, A. (2001). "Mapping spots: fishing areas or territories among islanders of the Atlantic forest (Brazil)." Environmental Change **2**: 1-12.

Béné, C. (1996). "Effects of market constraints, the remuneration system, and resource dynamics on the spatial distribution of fishing effort." Canadian Journal of Fisheries and Aquatic Sciences **53**(3): 563-571.

Bene, C. and A. Tewfik (2001). "Fishing effort allocation and fishermen's decision making process in a multi-species small-scale fishery: analysis of the conch and lobster fishery in Turks and Caicos Islands." Human Ecology **29**: 157-186.

Bockstael, N. E. and J. J. Opaluch (1983). "Discrete Modeling of Supply Response under Uncertainty - the Case of the Fishery." Journal of Environmental Economics and Management **10**(2): 125-137.

Bohnsack, J. A. (1996). Maintenance and recovery of reef fishery productivity. Reef fisheries. N. V. C. Polunin and C. M. Roberts. London, Chapman & Hall. **20:** 284-313.
Botsford, L. W., D. R. Brumbaugh, et al. (2009). "Connectivity, sustainability, and yield: bridging the gap between conventional fisheries management and marine protected areas." Reviews in Fish Biology and Fisheries **19**: 69-95.
Branch, T. A., R. Hilborn, et al. (2006). "Fleet dynamics and fishermen behavior: lessons for fisheries managers." Canadian Journal of Fisheries and Aquatic Sciences **63**(7): 1647-1668.
Cabrera, J. L. and O. Defeo (2001). "Daily bioeconomic analysis in a multispecific artisanal fishery in Yucatan, Mexico." Aquatic Living Resources **14**: 19-28.
Caddy, J. F. and F. Carocci (1999). "The spatial allocation of fishing intensity by port-based inshore fleets: a GIS application." ICES Journal of Marine Science **56**(3): 388-403.
Charles, A. T. (1995). "Fishery Science - the Study of Fishery Systems." Aquatic Living Resources **8**(3): 233-239.
Christensen, A. S. and J. Raakjaer (2006). "Fishermen's tactical and strategic decisions - A case study of Danish dernersal fisheries." Fisheries Research **81**(2-3): 258-267.
Christie, P. (2004). "Marine protected areas as biological successes and social failures in southeast Asia." American Fisheries Society Symposium **42**: 155-164.
Cinner, J. (2005). "Socioeconornic Factors Influencing Customary Marine Tenure in the Indo-Pacific." Ecology and Society **10**(1).
Cinner, J. and O. Bodin (2010). "Livelihood diversification in tropical coastal communities: a network-based approach to analyzing 'livelihood landscapes'." PLOS One **5**(8): e11999.
Cinner, J. E. (2007). "Designing marine reserves to reflect local socioeconomic conditions: lessons from long-enduring customary management systems." Coral Reefs **26**: 1035-1045.
Cinner, J. E. and S. Aswani (2007). "Integrating customary management into marine conservation." Biological Conservation **140**(3-4): 201-216.
Cinner, J. E., T. Daw, et al. (2009). "Socioeconomic factors that affect artisanal fishers' readiness to exit a declining fishery." Conservation Biology **23**(1): 124-130.
Cinner, J. E., M. Marnane, et al. (2005). "Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea." Conservation Biology **19**(6): 1714-1723.
Cinner, J. E., T. R. McClanahan, et al. (2009). "Gear-based fisheries management as a potential adaptive response to climate change and coral mortality." Journal of Applied Ecology **46**(3): 724-732.
Coulthard, S. (2008). "Adapting to environmental change in artisanal fisheries-Insights from a South Indian Lagoon." Global Environmental Change **18**(3): 479-489.
Cove, J. J. (1973). "Hunters, Trappers, and Gatherers of Sea - Comparative Study of Fishing Strategies." Journal of the Fisheries Research Board of Canada **30**(2): 249-259.
Daw, T. M. (2008). "Spatial distribution of effort by artisanal fishers: Exploring economic factors affecting the lobster fisheries of the Corn Islands, Nicaragua." Fisheries Research **90**(1-3): 17-25.
de Castro, F. and A. Begossi (1995). "Ecology of fishing on the Grande Rivers (Brazil): Technology and territorial rights." Fisheries Research **23**: 361-373.
Domeier, M. L. and P. L. Colin (1997). "Tropical reef fish spawning aggregations: defined and reviewed." Bulletin of Marine Science: 698-726.

Dreyfus-Leon, M. and P. Kleiber (2001). "A spatial individual behaviour based model approach f the yellowfin tuna fishery in the eastern Pacific Ocean." Ecological Modelling **146**(47-56).
Dupont, D. P. (1993). "Price uncertainty, expectations formation and fishers' location choices." Marine Resource Economics **8**: 219-247.
Durrenberger, E. P. and G. Palsson (1986). "Finding Fish - the Tactics of Icelandic Skippers." American Ethnologist **13**(2): 213-229.
Eggert, H. and R. B. Lokina (2007). "Small-scale fishermen and risk preferences." Marine Resource Economics **22**: 49-67.
Eggert, H. and P. Martinsson (2004). "Are commercial fishers risk-lovers?" Land Economics **80**(4): 550-560.
Eggert, H. and R. Tveteras (2004). "Stocastic production and heterogeneous risk preferences: Commercial fishers gear choices." American Journal of Agricultural Economics **86**(1): 199-212.
Feary, D. A., J. E. Cinner, et al. (2011). "Effects of Customary Marine Closures on Fish Behavior, Spear-Fishing Success, and Underwater Visual Surveys." Conservation Biology **25**(2): 341-349.
Forcada, A., C. Valle, et al. (2009). "Structure and spatio-temporal dynamics of artisanal fisheries around a Mediterrean marine protected area." ICES Journal of Marine Science **Advanced access**: 191-203.
Fretwell, S. D. and H. L. Lucas (1970). "On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development." Acta Biotheoretica **19**(1): 16-36.
Gaines, S. D., C. White, et al. (2010). "Designing marine reserve networks for both conservation and fisheries management." PNAS **Early edition**.
Galal, N., O. Hassan, et al. (2002). "Effect of a network of no-take reserves in increasing catch per unit effort and stocks of exploited reef fish at Nabq, South Sinai, Egypt." Marine and Freshwater Research **53**(2): 199-205.
Gatewood, J. B. (1983). "Deciding where to fish: the skipper's dilemma in Southeast Alaskan salmon seining." Coastal Zone Management **10**(4): 347-367.
Gatewood, J. B. (1984). "Cooperation, Competition, and Synergy - Information-Sharing Groups among Southeast Alaskan Salmon Seiners." American Ethnologist **11**(2): 350-370.
Gelcich, S., G. Edwards-Jones, et al. (2007). "Hetergeneity in fishers' harvesting decisions under a marine territorial user rights policy." Ecological Economics **61**: 246-254.
Gillis, D. M., R. M. Peterman, et al. (1993). "Movement Dynamics in a Fishery - Application of the Ideal Free Distribution to Spatial Allocation of Effort." Canadian Journal of Fisheries and Aquatic Sciences **50**(2): 323-333.
Goni, R., A. Quetglas, et al. (2006). "Spillover of lobsters Palinurus elephas from a marine reserve to an adjoining fishery." Marine Ecology Progress Series **308**: 207-219.
Gordon, H. S. (1954). "The economic theory of a common property resource: the fishery." Journal of Political Economics **62**: 124-142.
Gotanda, K., K. Turgeon, et al. (2009). "Body size and reserve protection affect flight initiation distance in parrotfishes." Behavioral Ecology and Sociobiology **63**(11): 1563-1572.
Guest, G. (2003). "Fishing behavior and decision-making in an Ecuadorian community: a scaled approach." Human Ecology **31**(4): 611-644.
Halpern, B. S. (2003). "The impact of marine reserves: Do reserves work and does reserve size matter?" Ecological Applications **13**(1 Suppl S): S117-S137.

Halpern, B. S., C. White, et al. (2011). "Using portfolio theory to assess tradeoffs between return from natural capital and social equity across space." Biological Conservation **144**(5): 1499-1507.
Hanna, S. (2001). "Managing the human-ecological interface: marine resources as example and laboratory." Ecosystems **4**(8): 736-741.
Hannon, B. (1994). "Sense of place: geographic discounting by people, animals and plants." Ecological Economics **10**: 157-174.
Helu, S. L., J. Anderson, et al. (1999). "An individual-based fishery model and assessing fishery stability." Natural Resource Modelling **12**: 231-247.
Hilborn, R. (2007). "Managing fisheries is managing people: what has been learned?" Fish and Fisheries **8**: 285-296.
Hilborn, R. and C. Walters (1992). Quantitative fisheries stock assessment: Choice dynamics and uncertainty. New York, Chapman and Hall.
Holland, D. (2008). "Are fishermen rational? A fishing expedition." Marine Resource Economics **23**: 325-344.
Holland, D. S. and J. G. Sutinen (2000). "Location choice in New England trawl fisheries: Old habits die hard." Land Economics **76**(1): 133-150.
Hutton, T., S. Mardle, et al. (2004). "Modelling fishing location choice within mixed fisheries: English North Sea beam trawlers in 2000 and 2001." ICES Journal of Marine Science **61**(8): 1443-1452.
Januchowski-Hartley, F., N. A. J. Graham, et al. (2011). "Fear of Fishers: Human Predation Explains Behavioral Changes in Coral Reef Fishes." PLOS One **6**(8): e22761.
Jennings, S. (2009). The role of marine protected areas in environmental management. Journal of Marine Science. ICES. **66:** 16-21.
Johannes, R. E. (1978). "Traditional marine conservation methods in oceania and their demise." Annual Review of Ecology and Systematics **9**: 349-364.
Johannes, R. E. (1978). Words of the lagoon: Fishing and marine law in the Palau district of Micronesia. Berkeley, University of California Press.
Johannes, R. E. and B. Yeeting (2001). "I-Kiribati knowledge and management of Tarawa's lagoon resources." Atoll Research Bulletin: 481-493.
Kaunda-Arara, B. and G. A. Rose (2004). "Effects of marine reef National Parks on fishery CPUE in coastal Kenya." Biological Conservation **118**: 1-13.
Kellner, J. B., I. Tetreault, et al. (2007). "Fishing the line near marine reserves in single and multispecies fisheries." Ecological Applications **17**(4): 1039-1054.
Lee, J., A. South, et al. (2010). "Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data." ICES Journal of Marine Science **67**: 1260-1271.
McClanahan, R. T., C. C. Hicks, et al. (2008). "Malthusian overfishing and efforts to overcome it on Kenyan coral reefs." Ecological Applications **18**(6): 1516-1529.
McClanahan, T. and N. A. J. Graham (2005). "Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas." Marine Ecology Progress Series **294**: 241-248.
McClanahan, T. and B. Kaunda-Arara (1996). "Fishery recovery in a coral reef marine park and its effect on the adjacent fishery." Conservation Biology **10**(4): 1187-1199.
McClanahan, T. and S. Mangi (2000). "Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery." Ecological Applications **10**(6): 1792-1805.
McClanahan, T. R. (2010). "Effects of fisheries closures and gear restrictions on fishing income in a Kenyan coral reef." Conservation Biology **24**(6): 1519-1528.
McConnell, K. E. and M. Price (2006). "The lay system in commercial fisheries: Origin and implications." Journal of Environmental Economics and Management **51**(3): 295-307.

Mistiaen, J. A. and I. E. Strand (2000). "Location choice of commercial fishermen with heterogeneous risk preferences." American Journal of Agricultural Economics **82**(5): 1184-1190.
Murawski, S. A., S. E. Wigley, et al. (2005). "Effort distribution and catch patterns adjacent to temperate MPAs." International Council of Environmental Studies Journal of Marine Science **26**: 1150-1167.
Oostenbrugge, J. A. E., W. L. T. Densen, et al. (2001). "Risk aversion in allocating fishing effort in highly uncertain coastal fishery for pelagic fish, Moluccas, Indonesia." Canadian Journal of Fisheries and Aquatic Sciences **58**(8): 1683-1691.
Pascoe, S. (2006). "Food for thought: Economics, fisheries, and the marine environment." ICES Journal of Marine Science **63**: 1-3.
Pauly, D., V. Christensen, et al. (2000). "Ecopath, Ecosim and Ecospace as tools for evaluating ecosystem impacts of fisheries." ICES Journal of Marine Science **57**: 697-706.
Pet-Soede, C., W. L. T. Van Densen, et al. (2001). "Can fishermen allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Achipelago, SW Sulawesi, Indonesia." Fisheries Management and Ecology **8**(1): 15-36.
Pet-Soede, C., W. L. T. Van Densen, et al. (2001). "Impact of Indonesian coral reef fisheries on fish community structure and the resultant catch composition." Fisheries Research **51**: 35-51.
Pita, C., H. Dickey, et al. (2010). "Willingness for mobility amongst European fishermen." Journal of Rural Studies **26**(3): 308-319.
Pollnac, R. B., R. S. Pomeroy, et al. (2001). "Fishery policy and job satisfaction in three southeast Asian fisheries." Ocean & Coastal Management **44**: 531-544.
Rijnsdorp, A. D., P. L. V. Broekman, et al. (2000). "Competitive interactions among bean trawlers exploiting local patches of flatfish in the North Sea." ICES Journal of Marine Science **57**: 894-902.
Rijnsdorp, A. D., A. Buijs, et al. (1998). "Microscale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms." ICES Journal of Marine Science **55**: 403-419.
Roberts, C. M. (1997). "Ecological advice for the global fisheries crisis." Trends in Ecology and Evolution **12**(1): 35-38.
Robinson, C. and S. Pascoe (1997). Fisher behaviour: Exploring the validity of the profit maximising assumption, CEMARE.
Robinson, J., M. A. Samoilys, et al. (2011). "The importance of targeted spawning aggregation fishing to the management of Seychelles' trap fishery." Fisheries Research **112**(1-2): 96-103.
Roy, N. (1998). "Fishing behaviour and the length of the fishing season." Marine Resource Economics **13**: 197-213.
Ruddle, K. (1996). Geography and human ecology of reef fisheries. Reef Fisheries. N. Polunin and C. Roberts. London, Chapman and Hall**:** 137-160.
Russ, G., A. C. Alcala, et al. (2004). "Marine reserve benefits local fisheries." Ecological Applications **14**(2): 597-606.
Russ, G. R. (2002). Marine reserves as reef fisheries management tools: yet another review. Coral Reef Fishes. P. F. Sale, Academic Press**:** 1-44.
Russ, G. R., A. C. Alcala, et al. (2003). "Spillover from marine reserves: Naso vlamingii at Apo Island, the Philippines." Marine Ecology Progress Series **264**: 15-20.

Salas, S. (2000). Fishing strategies of small-scale fishers and implications for fisheries management. Resource Management ad Environmental Studies. Vancouver, The University of British Columbia. **PhD:** 154.

Salas, S. and D. Gaertner (2004). "The behavioural dynamics of fishers: management implications." Fish and Fisheries **5**: 153-167.

Salayo, N., L. Garces, et al. (2008). "Managing excess capacity in small-scale fisheries: Perspectives from stakeholders in three Southeast Asian countries." Marine Policy **32**(4): 692-700.

Sanchirico, J. N. and J. E. Wilen (2001). "A Bioeconomic Model of Marine Reserve Creation." Journal of Environmental Economics and Management **42**(3): 257-276.

Seijo, J. C. and O. Defeo (1994). Dynamics of resource and fishermen behaviour in coastal invertebrate fisheries. Proceedings of the sixth conference of the International Institute of Fisheries Economics and Trade (IIFET), Paris.

Seijo, J. C., O. Defeo, et al. (1998). Fisheries bioeconomics: theory, modeling and management. FAO Technical Fisheries Document No 368. Rome, FAO.

Sesabo, J. K. and R. S. J. Tol (2007). "Technical efficiency of small-scale fishing households in Tanzanian coastal villages: an empirical analysis." African Journal of Aquatic Science **32**(1): 51-61.

Smith, M. D. (2005). "State dependence and heterogeneity in fishing location choice." Journal of Environmental Economics and Management **50**(2): 319-340.

Smith, M. D. and J. E. Wilen (2003). "Economic impacts of marine reserves: the importance of spatial behavior." Journal of Environmental Economics and Management **46**: 183-206.

Smith, M. D. and J. E. Wilen (2005). "Heterogeneous and correlated risk preferences in commercial fishermen: The perfect storm dilemma." Journal of Risk and Uncertainty **31**(1): 53-71.

Strand, I. E. (2004). "Spatial variation in risk preferences among Atlantic and Gulf of Mexico pelagic longline fishermen." Marine Resource Economics **19**: 145-160.

Teh, L. S. L., D. Zeller, et al. (2007). "Seasonality and historic trends in the reef fisheries of Pulau Banggi, Sabah, Malaysia." Coral Reefs **26**: 251-263.

Valcic, B. (2009). "Spatial policy and the behaviour of fishermen." Marine Policy **33**: 215-222.

Walters, C. (2000). "Impacts of dispersal, ecological interactions, and fishing effort dynamics on efficacy of marine protected areas: how large should protected areas be?" Bulletin of Marine Science **66**(3): 745-757.

Wilen, J. E., M. D. Smith, et al. (2002). "Avoiding surprises: Incorporating fisherman behavior into management models." Bulletin of Marine Science **70**(2): 553-575.

Williams, A. J., A. C. Ballagh, et al. (2008). "Harvest patterns and effort dynamics of indigenous and non-indigenous commerical sectors of the eastern Torres Strait reef line fishery." Continental Shlef Research **28**: 2117-2128.

Appendix 1. Fishers in Space - Key informant interview field guidelines

While conducting a key informant interview, try to bear in mind the following:

- Because the interviews are exploratory, the questions are not necessarily targeted at the important information (because we may not have known what the important information was when we designed the question). Therefore it is essential for the interviewer to use their own judgement and inquisitiveness to probe and elicit information which is relevant for the research questions. E.g.:
    - What factors affect where fishermen fish, and how?
    - What has driven changes in where fishermen fish?
    - What is the risk environment in which fishers operate?
    - What are the main differences between how different fishers make decisions on where to fish?
    - Other information helpful for designing the structured survey

- Try not to uncritically accept information. Often when you probe for more details you find that the first answer given does not always apply. E.g.
    - Interviewer: When do you plan where you will go fishing?
    - Fisher: I always plan out where I'm going to know the night before
    - Interviewer: So you always know where you're going the night before?
    - Fisher: Yes
    - Interviewer: Will you stick to the previous night's plan even if the weather is bad when you head out in the morning
    - Interviewer: No, of course you have to check the weather when you get out on the sea. If it is too windy you can't get out to [fishing ground]

  So in this example an uncritical interviewee would have recorded that the fisher always decides where he will go the night before whereas in fact the fisher considers at least one factor (weather) as he is heading out to fish.

- Use prompts and questions which start with "How", "What", "Where", "Why" to avoid leading questions. Questions beginning with "Is", "Do" etc tend to be more leading, and there is a risk of the interviewer's knowledge being recorded rather than the fishers (and as you are already involved in this project, this is not good use of time!!)

- Write up KI interviews as soon as possible after the event (and certainly, where possible before the next KI interview), brainstorm between the interviewers to capture the important details and learnings. Write summary notes at the same time as the transcription.

Data management:
Save the interview recording with the filename: KI 01 090324.WMA

Which means a Key Informant interview with fisherman number 01, from March 24th 2009 (note that it is in the format Year Month Day.)

Use the same format for writing up the transcript as a word file e.g.:
KI 01 090324.doc

Fishers in Space - Key informant interview guide

Individual details

Name of fisher:

Age:
Fishing gear types (indicate primary gear type):
Boat type & length:
Engine type and size:
Landing site:
Date of interview:
Time of interview:
Name of interviewers:

A) Background information of fisherman:

(i) When did you start fishing?
(ii) Why did you decide to become a fisherman?
(iii) Are you from a fishing family?
(iv) Do you own your own boat? If not, who does?
(v) How many crew do you have? How do you share the catch?
(vi) How many days per week do you fish? How many hours a day?
(vii) What technology do you have on board? GPS? Fish finder?
(viii) What do you see yourself doing in 10 years time? Still fishing?

B) Learning about locations

I'm specifically interested in finding about how fishermen decide where they are going to fish.

(i) How did you learn how to fish?
(Did someone teach them? Did they learn on their own?)

(ii) How did you learn **where** to go to fish?
Prompts:
- Where actual fishing sites are?
- How to identify or choose between potential sites
  (eg. from environmental signs, does this change with season?)

C) Map based questions

Show the interviewee the map and ask:
(i) Which areas do you normally go fishing in each season?
(ii) If a very large area is indicated ask if he spends more time in one particular area? Why is your fishing focussed in these areas?
(iii) Why not go fishing another site?why not this sites?
(iv) Are there areas you fish now which you didn't used to fish ~5 years ago? Why did you start fishing in these areas?

(v) Are there areas you used to fish ~5 years ago which you don't fish now? Why do you not fish there any more?
(vi) Characteristics of this fishing area……..
What features attract or distract fishing……
How frequently do you go fishing here? Why?
(vii) Do you always fish same place? If not, what other areas and describe them
(viii) Do you fish in new areas where not fished before? Why/ Why not?

D) Navigation and Technology

(i) What methods do fishermen use to navigate to a fishing location? Do they have:
- GPS
- Sounder
- Compass
- Any other technology for navigation?

Prompt for each new technology:
(ii) When did they get new technologies?
(iii) How has it changed fishing behaviour?
(iv) Was it difficult to learn to use it?

D) Spatial decision-making

(i) Before you go to sea for the day, how do fishermen decide which general area they are going to fish in?
- Ask about fishermen in general & also key informant's own methods
- Make sure to ask if these factors change in different seasons

Prompts to use & ask why these factors are important for location choice

Weather/state of the sea?
Lunar/tides?
Currents?
Habitat type?
Target species?
Site resting time?
Familiarity? Habit/tradition?
Previous catch?
Aggregation of fish?
News about good catches?
A new fishing ground they have heard about?
Costs? (fuel, bait, spare parts)
Regulations/closed areas?
Are you influenced by the fish buyer?
(do they tell you which species to target?)
The presence of other fishermen?

- Do you fish with other boats?
- Who (kinds of boats / gears / landing site)
- Why? Why Not?

(ii) How much time do you spend thinking and planning where you are going to fish before you go to sea?
(iii) Is there any public information that is used to decide where to go fishing? (eg. lunar charts, SFA, weather, tide timetable, etc)
(iv) Do you ever change your plan and fish in a different place than you had planned to? Why? Describe an example?
(v) Do you normally go to sites that you already know or do you explore new areas?
- How do you explore?
- How often?
- What leads you to explore new grounds?
(vi) When they get to the area you are going to fish in, how do fishermen decide the exact place they are going to deploy their gear?

E) Risks associated with fishing:

Some fishermen take more risks than others while they are fishing. For example, some fishermen put themselves in more danger than other fishermen. We would like to understand the types of risks that fishermen face and why different fishermen take these risks.

(i) What are the risks/hazards fishers are exposed to when fishing? What do you worry about happening when you are fishing?
(ii) Do some fishermen take more risks than others? What are they? (Describe a situation?)
(iii) Are there locations that are more risky than others? Why?
(iv) What time do you come home from fishing?
- Will anything make you stay fishing longer?
- Do you ever come home in the dark?
- What if you find a lot of bourgeois when it's time to leave?
(v) Do you have fuel left in your boat when you reach your landing site?
- How much normally?
- Do you have a reserve? How much?
- Have you ever run out of fuel…what happened?
- Does this happen often?

F) Knowledge sharing:

We want to understand if and how fishermen share information with each other

(i) If a fisherman gets a really good catch, will he tell other fishermen where he caught those fish?
- Is it species specific? (Karang? Bourgeois?)
- Who do you share information with? Why?
- Who don't you share information with? Why?

G) Fisherman's understanding of spill over:

(i) What do you think is the purpose of marine parks?

(ii) How do marine parks affect fishermen?
(iii) Do you think that fishermen fish outside of, but close to the marine parks? Why?
(v) Do you think fishing near the MPA is a good strategy? Why?

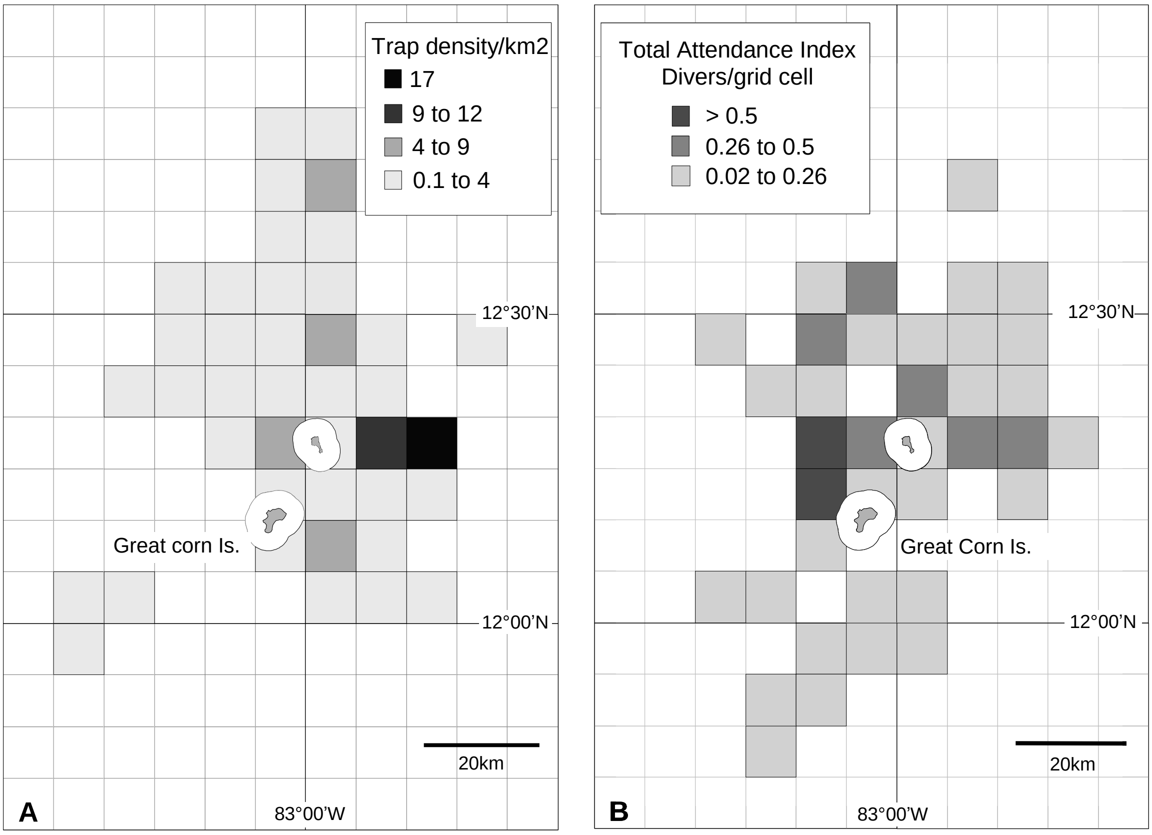
G) Fishermen's experience of displacement

Were you already a fisherman when fishers were displaced from the Marine Park or land reclamation?
If so….

- How did it affect your fishing? How did you respond?
- How did it affect where you fished?
- Did you start fishing new areas that you didn't fish before?
- How did you find new places?
- What was the overall effect on a) your catches? b) your profits

H) Fisherman's views and advice over this project

(i) Do you think these questions will help us to understand why fishing is focussed in some areas?
(ii) Do you know about plans for VMS on the small boats? What do you think will be the response
(iii) Do you think fishermen will be willing to confidentially share their VMS data with our project to produce general maps like this (show interviewee figure below)?
(iv) Do you have any questions or suggestions about the project?



Name:

Appendix 2. Interview questionnaire

Survey of Fishers (to be conducted with boat captains)
Date____________ Site where fishing is based__________ **Interviewer_________**
Comments on the interview:

Ethical statement

Read to interviewee and ensure that they understand.
This interview is for a study by SFA, and the University of East Anglia in Seychelles and in Kenya. It is to understand the decisions fishermen make. We will circulate the information that we collect, but your answers will not be linked in any way to your name.

Helping us with this survey is voluntary. If you do not want to take part or do not want to answer any questions, there is no penalty.

This interview should take approximately 40 minutes. Do you have any questions? Are you happy to continue with the interview?

Fishing History/Practises

1. **How long have you been a fisherman?**
2. How long have you been fishing from XXXX?
3. **Please tell me why do you continue to fish?**

4. Do you expect to be fishing in 5 years time? Y / N / DK
   a. *If no or DK,* Why is that?
   b.
5. **How many days per week do you normally go fishing?**
   a. In the high season
   b. In the low season
6. **How many days per month would you not fish because of bad conditions?**
   a. In the high season
   b. In the low season
7. **Which fishing gears do you use in the NEM and SWM?**

Gear *(separate trap types, trolling etc)*	Typical		Description (net length, net gauge, # traps, etc.)
	NE	SW	

8. *If valuable gears,* Do you own these gears?
9. **Which gear(s) do you use most often during NEM?** *Record if all if uses more than one gear per trip (e.g. sets trap then handlines)*

10. On a typical day using this gear, what time do you leave the shore?
    a. and how much later do you return to shore?

11. **How many crew do you fish with in total (including interviewee)?**

12. **Are you the captain (i.e. do you decide where/when/how to fish)?**

I realize that even in the high season, some days you catch a lot of fish, other days you may not catch many fish.

13. Please think about your best day's catch?
    a. How much fish can you get in your best catch?
    b. How much effort would that take (*Man-hours*,*traps etc*)
14. Now please think about the worst catch you get?
    a. How much fish do you get per day in your worst catch?
    b. How much effort would it take on your worst day?
15. Now think of the most normal day
    a. How much fish do you normally catch?
    b. How much effort do you normally put in?
    c. How much is your catch normally worth?

	Best day	Worst day	Typical day
Catch			
Daily effort (hrs, traps etc)			
		Value:	

Catch Units (kg, packets):

Effort Units (hrs, # traps):

16. Are these catches for: whole crew / individual?
17. What kind(s) of fish do you get most with your usual gear in the high season?

18. So typically, you catch XXXX. Imagine if your catches declined so that you were consistently catching only half as much as that, what would you do?

Do not prompt

- ☐ Keep fishing — Why? _________________
- ☐ Fish harder (increase effort) — How? _________________
- ☐ Fish less (decrease effort) — What would you do instead? _________________
- ☐ Change fishing area — Where would you go? _________________
- ☐ Change fishing gear — Which gear? _________________
- ☐ Stop fishing — What would you do instead? _________________
- ☐ Other — Describe_________________

19. On a typical day, what proportion of the fish you catch is kept for yourself, family or friends rather than sold? none / few / some / most / All
    %: 0 / 1-20 / 21-50 / 50-95 / 95+
20. Who do you normally sell your fish to (specify the type of buyer) if several, give an indication of % each? (e.g. Hotel, local consumer, middleman, mama karanga, co-op)

Type of buyer	Proportion of fish	Types/sizes of fish (if diff. markets)
	few / some / most / all	
	few / some / most / all	
	few / some / most / all	

21. **Do you normally fish from a boat?** Y / N / Sometimes
22. **If so do you own the boat?** Y / N / Partly
23. **What type of boat?**
24. **What is the length of the boat?**
25. **How is the boat powered?** ☐paddles, ☐sail, ☐engine - HP____, Other **……..**

If the boat is powered

26. In the high season, normally how much fuel is in your boat when you leave shore?
27. How much do you normally return with?
28. Have you ever run out of fuel at sea? Y / N
29. Do you carry reserve fuel with you? Y / N

30. **How do you normally navigate to / find your fishing site?**

31. **In the boat, do you have?**

GPS: Y / N *From this project?* ☐ *When acquired:*	Echo-sounder Y / N *When acquired:*	Compass Y / N
Plotter Y / N *When acquired:*	Fish finder Y / N *When acquired:*	Charts Y / N

a. **Other navigational tools……………………………**

For new technologies…

b. How long ago did you acquire these technologies?

c. Have these changed the way that you fish? Y / N / sometimes

How?

32. **Do you (your boat) usually fish alone at sea, or with others (other boats)?**

alone / with others / sometimes with others (*record when*)

33. Does fishing close to other fishers affect the amount you catch? Y / N / sometimes
    a. How?

Spatial Habits / Strategy

34. **Please look at this map. Can you please indicate where you normally fish with your main gear.** *(Note: try to capture furthest sites up/down the coast)*
    a. **during the NWM?**
    b. **during the SEM?**

Map	Cells	Gear	Season	Notes

35. What is the furthest place you go?
    a. Offshore
36. How deep is the water where you usually fish? Min___ Max____
37. What is the bottom like where you usually fish?
38. **Can you indicate places where you can't fish? (*close to or within the range indicated in previous question?*) Why?**

Map	Cells	Gear	Season	Notes

If the interviewee has been fishing here for at least 10 years

39. **Do you fish in the same places as you did 10 years ago?** **Y / N**
Or if not. Do you fish in the same places as you did when you started fishing here?

If not…

a. **Can you indicate places where you fish now that you didn't fish in the past? Why is this so? How did you find them?** ***(i.e. New Grounds)***

Map	Cells	When started fishing there?	Why start fishing there?	How did you find it?	Notes

a. **Can you indicate any places where you used to fish in the past but do not fish now? Why is this so?** ***(i.e. Lost Grounds)***

40. Have you ever lost/been displaced from a fishing ground?

Enter both of these questions in the grid below

Map	Cells	When stopped using site	Why stopped (note displacement)	Notes

If there is a known displacement in the area that has not been mentioned:

41. Did you used to fish in the area that is now the [*displacement*]?

If specific displacement of fishing from areas has been mentioned (e.g. MPA, development etc)…

42. **What did you do when you could no longer fish in [*displacement area*]?**
43. **Do you ever explore new fishing areas that you haven't fished before?** Y / N
    a. **How do you do this?**
    b. **When would you explore rather than going to an area you already know?**

In Kenya…

44. Has the BMU system affected where you go fishing? Y / N
    a. How? Why? Why not?

Short-term decision making

When you go out fishing, how do you decide where to go? What things do you think about when you decide?
Are there any other things you consider?

For any factors not mentioned, ask if the fisher considers it. Indicate for each factor whether it is volunteered by the interviewee (V), whether they agree when asked about it (Y) or whether they disagree when asked about it (N).

Factor	Answer	Description/Notes
45. Weather and sea state	V Y N	
46. Currents	V Y N	
47. Lunar Phase	V Y N	
48. Your experience of recent catches (e.g. big or poor catches)	V Y N	
49. Where you have fished recently (e.g. not fished there in a while)	V Y N	
50. News from other fishers	V Y N	
51. Fishing expenses (e.g. fuel, bait)	V Y N	
52. Price of fish	V Y N	
53. Where other fishers are fishing	V Y N	
54. What you think the fish are doing (e.g. aggregations, catchability)	V Y N	
55. Other *Don't prompt*		

56. So, when choosing where to go fishing, you consider [*list factors with Ys*]. Of these, which factor affects your choice most often? *Circle the most important.*

Communication

57. **Before you go to sea, do you usually seek advice from, or discuss with anyone, to help decide where to go fishing?**

If yes

58. **Who do you talk to about this?**

Relationship	Notes (*#people, location, gear type, means of comms*)

Note if middleman, fishers of same gear, crew, fishers of different gear, fishers from kin-group, fishers from other units (vessel, landing site), BMU, Other

59. **Do other fishermen find out how much you caught while fishing?**

Y / N / sometimes *specify occasion or reason*

a. How?

60. **Do other fishermen usually know where you went fishing?**
Y / N / sometimes *specify occasion or reason*

a. How?

61. **Do you have access to a mobile phone?** Own / Has access / No access

a. Do you use it to communicate with other fishers while at sea?
never / sometimes / frequently

b. Why/Why not?

c. **Does your mobile phone help you as a fisherman?** Y / N / sometimes
How?

d. How long ago did you start to take your mobile to sea?
e. Have changed the way you fish because you have a mobile? Y / N
How?

Risk Aversity

62. Do you ever go fishing beyond the pass/reef during a big swell? Y / N
(If relevant to local conditions)

Perception of effort density

63. Relative to the size of your fishing grounds and the amount of fish, how is the amount of other fishers/boats/gears in your fishing grounds?
could be more fishing / is about right / already too much fishing / DK

64. If there were twice the number of other fishers/boats/gears in your fishing grounds, how would that affect your *individual* catches?
no effect / would catch less / would catch more / DK

65. If there were half the number of other fishers/boats/gears in your fishing grounds, how would that affect your *individual* catches?
no effect / would catch less / would catch more / DK

Perception of Spill Over

If a fisheries closure (park/MPA) is in the area ***whether or not*** *the fisher fishes near it.*
Record categorical answers as well as any details or explanations given by the interviewee

66. **Does the closure affect the amount or value of your catch?** Y / N / DK
How? Why is that?

a. Overall how does the closure affect you as a fisherman?
no effect / negative effect / positive effect / DK

67. **Please tell me how you think fish inside the closure compares with fish in other areas:**

a. **amount of fish:** more fish inside / no difference / less fish inside / DK
b. **size of fish:** larger inside / no difference / smaller inside / DK
c. **types of fish:** same kinds / different kinds *(add below)* / DK

More INSIDE closure	More OUTSIDE closure

68. **Do fish inside the closure always stay inside, or do they sometimes move out?**
stay inside / move outside / sometimes / DK

69. **If they sometimes swim of the closure, are they ever caught by fishermen outside?**
Y / N / DK

70. **Do you think that you catch fish that swim out of the closure?**
Y / N / DK

71. Do any fishermen fish close to (but outside) the boundary of the closure?
    a. Why do they do that?

72. **What are fishers' catches like next to the closure compared with similar places far from the closure?**
    a. **Amount:** More near closure / Same / Less near closure / Depends / DK
    b. **Type of fish caught:** same kinds / different kinds *(add below)* / DK

Near closure	Far from closure

Household Socioeconomics

73. Where are you originally from? ....

This district	this island	this country	other country

74. Why did you move to XXX?

Fishing	Other work	Land available	Family & friends	Health/spiritual
Other				

75. How many people live in your household?

Men	Women	Children (<18)

76. **How many people depend on your income as a fisherman? _______**

77. **How much does your fishing contribute to the household income?**
a little / some / most / All
%: 1-20 / 21-50 / 50-95 / 95+

78. **What sources of income do you have personally?**

Income/Occupation	**Rank**
Fishing	

79. **Please rank which source is most important for you** *include fishing in the ranking*

80. Do you have transport at your house?

Bicycle	Motorcycle	Small Car	Pickup/Jeep

Other……………..……………..

81. What is the roof of your house made from?

Thatch	Metal	Tile

Other……………..……………..

82. What is the floor of your house made from?

Dirt/soil	Bamboo/palm	Plank Wood	Cement	Finished (tiles, etc.)

Other……………..……………..

83. What are the walls of your house made from?

Bamboo/ thatch	Wood (plank)	Stone block	metal	Cement

Other……………..……………..

84. Do you have these items in your house?

VCR/DVD	Cable TV	Air conditioning	Freezer
Computer	Internet access	Water heater	Dishwasher

85. What is the approximate monthly expenditures of your household?

86. If you wanted to borrow money, for example to buy a boat/equipment. Can you borrow money?

__no, __from friends/family, __from middlemen, __from group (cooperative, etc), __revolving fund __ from financial institutions, other………………………………

87. Do you currently have any debts/loans? Y / N

If so, to whom?

__bank, __middleman, __friend/family, __boat/gear owner

other………………………………………….

a. Does this debt influence where or how you fish? Y / N

If so, how?

Financial time horizons and discount rate

For this question, choose X and Y based on typical daily catch value (Kenya values)

Value of typical catch	*X*	*Y*
< 100 Ksh	*1,200*	*1,500*
101 – 500 Ksh	*4,000*	*5,000*
501 – 2,000 Ksh	*20,000*	*25,000*
2,001+ Ksh	*60,000*	*75,000*

Would you rather receive *X* now, or get *Y* after a 6 month delay?

Repeat the question reducing / increasing the time delay until the respondent changes their answer.

if 'X now'	***6 months***	*if 'wait for Y'*
3 months		***1 year***
2 months		***2 years***
1 month		***4 years***
2 weeks		***6 years***
1 week		***8 years***
3 days		***10 years***
1 day		***>10 years***

Circle the time when the respondent changes from 'now' to 'wait' or vice versa.

Demography

88. **Age**
89. Religion
90. Ethnicity
91. **Have you had any health problems that have affected your fishing?** Y / N
    a. **How did it affect your fishing?**

    b. **Is this better now?**

92. **What is the highest level of education you have attained?**
Interviewer enter minimum number of years to attain that level of education:

Further collaboration consent questions

93. *In Seychelles:* Would you be willing to help further with this project by collecting data on where you go fishing? We will share your data with you and provide you with your own maps of where you fish. This data will be kept secret and only presented in low-resolution and anonymous form?
    In Kenya: It would be useful for the survey team to know your name for two reasons: a) So that we can link the information from this interview to any information if you collaborate with us later in the project, and b) so that we do not accidentally try to ask you the same questions again. Your name will NOT be entered into our database. This ensures that the information from this survey will be anonymous and not linked to you personally in any way.

Reliability of interview

For interviewer to complete after interview

94. *Please indicate to what degree you feel the respondent was reliable in answering the survey:*

(….) very reliable (….) moderately reliable (….) not very reliable

If you feel answers were unreliable, please explain why below and, if possible, explain to which questions you think the answers given are particularly unreliable

Appendix 3. Practicalities of Monitoring Artisanal fishers with handheld GPS and Logbooks.

Our experience of using hand held GPS and logbooks for monitoring artisanal fishers highlighted the resources required and things that have to be considered in order to produce sensible data. The quality of data to be achieved will depend greatly on several aspects including the resources and equipments employed as summarised in the table below. Their also few nature based factors that are beyond individual control which may affect data quality but with a good field collaboration these risks can be greatly reduced.

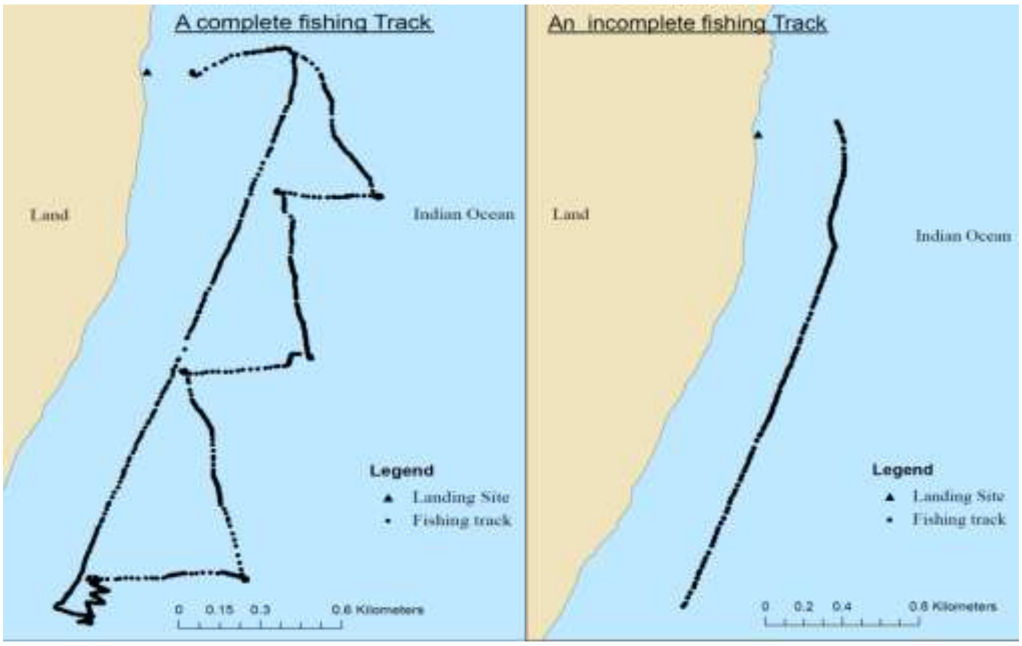
Equipment	Resources
Handheld GPS units (Garmin Geko 201) Logbook Quality Rechargeable Batteries Purpose-made Battery extension cable Downloading cable Field laptop	Full time fieldworker with transport for 19 months Development of dedicated database (1 month) GIS and processing time and expertise (2 weeks of analysis meetings with advanced GIS and database support) Data entry and checking (~4 months full time)

Challenges

Analysis of the data relies on identifying which trip points represent where fishers fish. This is difficult without complete fishing tracks for each trip, and can lead to spatial biases. Of the 1127 fishing trips tracks from 6 landing sites in Kenya, 55% had complete fishing tracks the rest had gaps in the trips (Figure 2). Across the gear types spear gun had more incomplete tracks than complete tracks (Figure 3). Incomplete fishing tracks are caused by the GPS failing to record the GPS point, a result of loosing power or satellite signal.

Initial monitoring was limited by the poor battery life of the AAA batteries that are standard with the Garmin Geko units. This increased the likelihood of incomplete trips, led to frustration with participating fishers and high financial costs and environmental impacts of the project. To improve the battery life, purpose-made battery extension cables were manufactured by CalNorthern Systems (http://calnorthern.com/calnorthbase/). These allowed the unit to be powered by larger AA batteries. In addition we moved to the use of Low Self Discharge Rechargeable Batteries (Enelong AA 2100mAh).

The Geko 201 GPSs lost satellite signal on immersion partly explaining why spear fishers had more uncompleted trips than complete fishing tracks. Better results were obtained when fishers were asked to attach the GPS to the fishing buoy so that it stays afloat all the time during the fishing Trip.



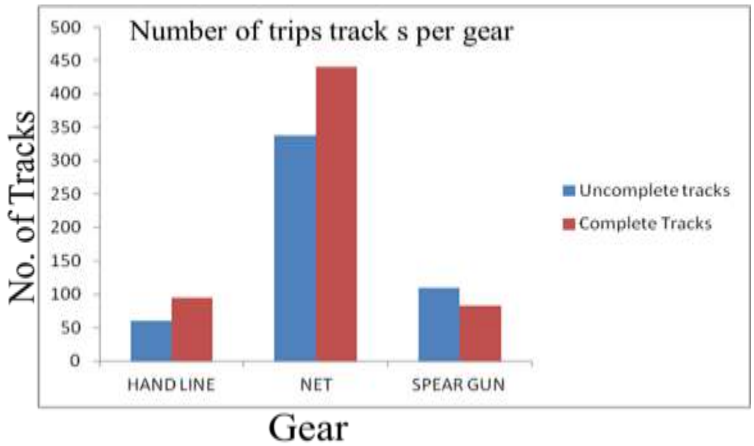


Figure 2. Proportions of complete and incomplete tracks recorded by the GPS units.

Challenges	Possible Solution
GPS malfunction and erratic values	Use a more Advanced GPS with latest firmware (Geko 201 not recommended with 2.7 firmware)
Short Battery life	High quality, rechargeables (e.g. Sanyo Eneloop) AA Battery extension
GPS loosing Signal (especially divers)	GPS attached to the fishing buoys
Consistent Fisher Cooperation	Long-term personal relationships, regular feedback and field visits, links to long term projects
Interpretation and analysis of track data	Spatial data analysis and manipulation expertise (GIS, Matlab, Access). Use of speed, turning angle etc to identify fishing tracks.

Conclusions and recommendation

It is possible to collect high resolution spatial behaviour data from small scale fishers using hand-held GPS. However the method involves considerable practical challenges and requires a large amount of resources. In particular, technical problems with GPS malfunction and battery life were not foreseen. Long-term engagement with fishers, regular contact in the field and regular plotting of results are necessary to identify and address issues.

Appendix 5. Validation of the Surveymap data

Where the same fishers answered survey questionnaires and carried GPS units, it was possible to do a simple cross-validation of the two methods as indicators of fishing resource space. Shapes produced in response to the surveymap question "*Please look at this map. Can you please indicate where you normally fish with your main gear*" were overlaid with all GPS points recorded by the same individual fisher. None of the GPS points and surveymap shapes overlapped precisely. For three fishers, the survey map shape gave a rough indication of the range of the fishing area. For two fishers GPS points were distributed over a much larger area, than the surveymap shape and for 3 others the GPS points were constrained within a much smaller area than the surveymap shapes (although one of these had only two recorded tracks) (Figure 1). Similarly inconsistent results were found for four validation plots in the Seychelles but these are not shown here for confidentiality reasons.

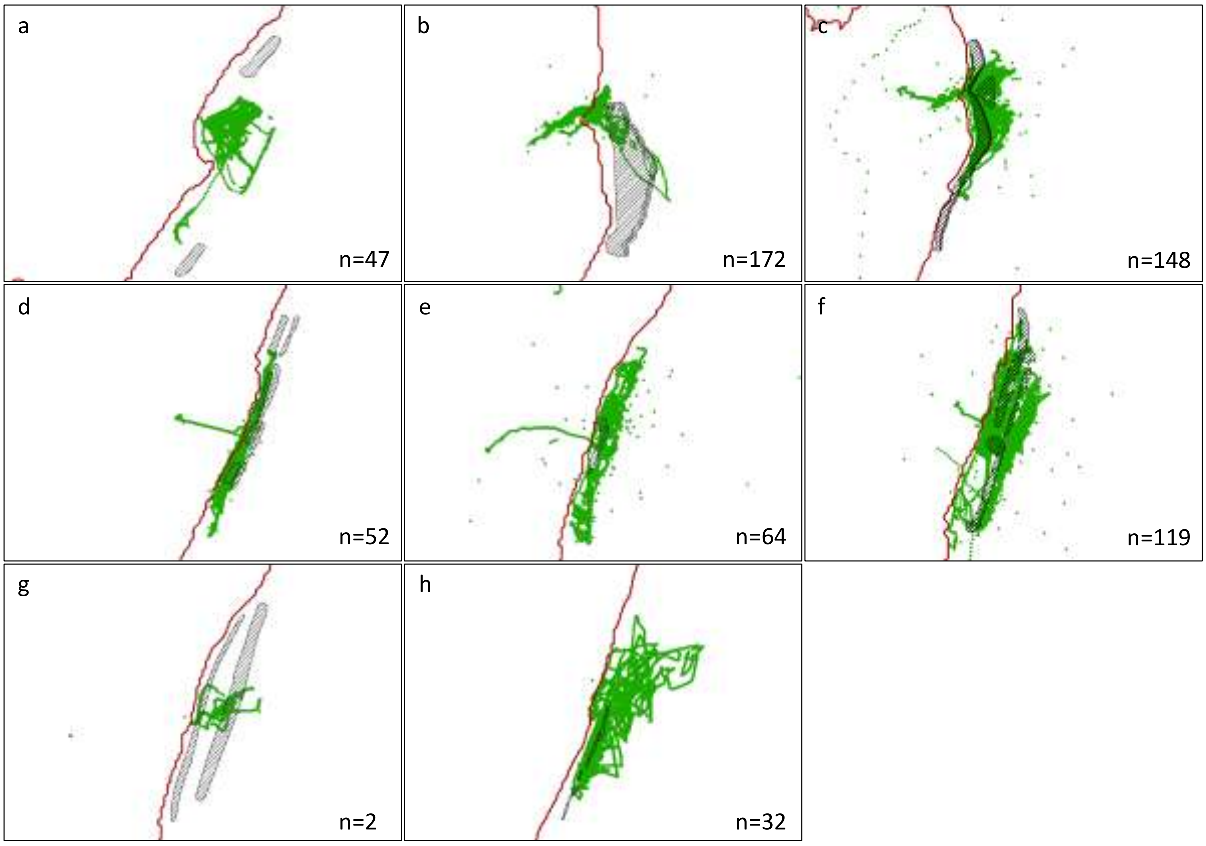


Figure 1. Validation plots of surveymap and GPS data points for 8 fishers who cooperated with both methodologies. Green dots indicate GPS points, hatched areas are surveymap shapes indicating normal fishing grounds. Number of tracks recorded for each fisher is shown.

A range of explanations could explain the lack of overlap:

- Errors were made in drawing the surveymaps due to participants failing to relate to the map or understand the scale. For example the scale of the map may have been underestimated in Figure 1e and h, and overestimated in Figure 1a.
- A change in behaviour occurred between the survey question being asked and the GPS monitoring (which occurred later)

- Areas may have been identified correctly by the survey map which are fishing sites, but which were not visited during the GPS mapping period. This could explain discrepancies in Figure 1g and b, but not a
- Fishers may have purposely avoided mapping out their actual fishing grounds out of suspicion. This seems particularly unlikely in the case of these eight individuals who went on to volunteer to be GPS carriers for the project.

The lack of overlap generally seen between these two methodologies raises questions about the accuracy of field drawn fishing behaviour maps. The surveymap method is a relatively fast and cheap method to collect spatial fishing behaviour data. Although it may give a general indication of the scale or range of fishing area over a large population of fishers, they do not seem to be suitable for accurate mapping of fishing locations. Certain circumstances or individuals may produce reliable data, but this needs to be validated before making strong conclusions.