Assessing conservation of a tropical African estuary: Waterbird disturbance, livelihoods, and ecotourism

MSc Thesis

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Abstract

The aim of this study was to evaluate the potential costs and benefits of increasing conservation in the Sabaki River Mouth Important Bird Area. This was achieved by assessing the vulnerability of waterbirds to disturbance from human activity in the estuary, the current use and importance of the area to local livelihoods, and the value (current and potential) of tourism. Waterbird densities and levels of human activity were quantified from 20 September to 25 November 2010 in the intertidal area of the Sabaki River Mouth Important Bird Area on the central Kenyan coast. Household surveys were conducted in the adjacent Sabaki Village from 15 October to 24 November 2010 (N = 190). The current and potential value of ecotourism was investigated by recording visitation rates and interviewing visitors to ascertain their preferences and willingness to pay an entry fee from 5 October to 4 November 2010.

Three types of response variables were collected at six sites to characterize relative responses of waterbirds to simulated human disturbances. These were 1) changes in bird density within a 40 m radius of a stationary disturbance (D40); 2) minimum distance of birds from the source of a stationary disturbance (≤ 40 m); and 3) the time for 90% of original bird abundance to recover following a mobile human disturbance which caused all birds to flee the immediate vicinity. Disturbance response metrics were estimated from these variables by calculating normalized mean residuals from regressions of density (D40) and minimum approach distance against expected densities measured in the absence of disturbance, for 14 waterbird species. The majority of potential disturbance events were from cattle and fishers; of these 64.4% were mobile disturbances. Foraging waterbird dispersion and human disturbance levels differed between sites but were not directly related to one another. Disturbance levels were distributed non-randomly throughout the estuary and varied between user-types (cattle, fishers, tourists and beach boys). By quantifying the response of species along a gradient of response based on the three variables measured, it was possible to identify which species exhibited strongest and weakest avoidance responses to disturbance. Strongest avoidance responses were exhibited by flamingos (Greater Flamingo, Lesser Flamingo) and Terek Sandpiper. Overall concordance among the three disturbance metrics (listed above) was high, but the statistical significance of each metric varied across species. The concordance between metrics suggests that two metrics (density surrounding disturbance and distance from disturbance) may be used as surrogates to conduct rapid assessments of interspecific variation in adaptive responses to disturbance.

Livelihood composition was highly diversified among traditional rural activities. The local community mainly comprises subsistence agriculturalists and pastoralists and the majority of cash income is derived from employment (24.5%) and business (20.3%). Including the value of subsistence

production, collection of water contributed the highest percentage of household income (16.0%) followed by crop production (14.0%) and fuelwood collection (13.1%). Business and employment collectively contributed 16.0% of income, of which 6% was tourism-related. Between 84 and 99% of all resource extraction and agricultural activities occur within the boundaries of the Important Bird Area, and the community has little alternative. The local people are highly dependent on the environment (56% of income is derived from natural resource use) and do not receive benefits from social welfare or government pension programmes. The Important Bird Area thus provides a safety net against shocks to a community of more than 2000 people.

In a 30-day period, visitation rates were as follows: 192 local tourists, 270 foreign tourists, and 375 students. Of the 148 foreign and local tourists interviewed, 96.8% were willing to pay an entry fee. Aggregate willingness to pay (2500 US$ per annum) may be enough to offset some, although little, of the potential opportunity costs to locals of restricting resource use in and around the estuary. Improving tourism infrastructure significantly increases aggregate willingness to pay (11 400 US$ per annum) and implementing a bird hide and boardwalk would enhance the tourism value of the estuary. Provisioning of alternative livestock watering areas away from the estuary, promoting sustainable fishing activities, and implementing a boardwalk on the periphery of the estuary to reduce movements of tourists on the intertidal flats represent the most favourable modes of managing biodiversity and achieving greater ecotourism value in the region. Gazetting of the area as a community reserve and implementing community-based natural resource management and infrastructure for ecotourism has the potential to contribute significantly to local livelihoods as well as fulfil conservation objectives at an Important Bird Area.

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CHAPTER 1. Literature Review

Waterbird conservation and human livelihoods

Loss and degradation of wetland ecosystems in sub-Saharan Africa has accelerated in the face of rising poverty, human population growth, and unsustainable development (Moser 1996). Wetlands provide key habitats to waterbirds and are a vital component of human livelihood for many societies in Africa. Thus the need to understand the threats facing wetland ecosystems and the importance of wetlands is critical to conservation planners and policy-makers (Dovie et al. 2005). The accelerating loss and degradation of wetlands has led to a long-term decline in waterbird populations, with 45% of populations in the African-Eurasian Flyway currently exhibiting declining trends (Delaney 2008). Waterbirds are indicator species for ecosystem health and are economically important for subsistence hunting and as a tourist attraction (Kuijken 2006). Human use of wetlands may lead to disturbance of local biota and, in turn, impact the value of wetlands to livelihoods and biodiversity. Resource use and disturbance from humans is among the top five threats to waterbirds (Delaney 2008). However, only one study to date has examined the impacts of disturbance by rural subsistence users (Quan et al. 2002).

Disturbance may particularly impact foraging waders in estuaries where space and time limit foraging opportunities (Cayford 1993, Burton et al. 2002, Goss-Custard et al. 2006). Further decreases in foraging time may incur energetic costs and compromise individual survival. Excessive disturbance levels may lead to effective habitat loss by forcing birds to abandon otherwise suitable feeding areas (Knapton et al. 2000), and loss of habitat is of particular concern for the conservation of migratory waterbirds in East Africa (Nasirwa et al. 2006). The conservation status of waders is particularly critical, with 53% of species exhibiting declining trends (Wetlands International 2010).

In light of the unfavourable conservation status of waterbirds and the importance of wetlands for waterbirds and livelihoods of the rural poor, conservationists increasingly seek ways to achieve conservation through integrated research and management schemes. This literature review briefly examines the history of waterbird disturbance research and describes the link between waterbird conservation and rural livelihoods in an East African context. By studying two traditionally disparate fields, firstly one aspect of waterbird conservation and secondly the socioeconomic value of critical waterbird habitats, researchers can develop evidence-based solutions to achieve conservation at sites of conservation priority in impoverished areas.

A brief history of disturbance studies

Studies of the immediate effects of disturbance to waterbirds reveal information about threats on a local-scale (Nisbet 2000). Early studies of disturbance on wintering waterbirds examined the behavioural responses of waterfowl to disturbance stimuli (Hume 1976, Batten 1977, Owens 1977, Tuite et al. 1983), and the need to assess the consequences of disturbance became apparent during the late 20th Century as increasing human populations and intensity of recreation led to increased potential disturbance levels (Korshgen et al. 1985, Madsen 1985, Davidson and Rothwell 1993). However, waterbird disturbance remained poorly documented throughout this period (Belanger and Bedard 1989). Considerably more literature on waterbird disturbance was published in the late-20th Century and examined the immediate effect of disturbance by studying the behaviour of birds as surrogate measures (Burger 1981, 1986, Klein 1993, Smit and Visser 1993, Klein et al. 1995, Fitzpatrick and Bouchez 1998). Increasingly, researchers attempted to model the potential impacts of disturbance (Cayford 1993), but data requirements make these types of studies unrealistic when little is known about the complexity of factors influencing waterbird populations. More recently, landscape approaches have been taken to examine the relationships between waterbird distribution and human activity (Burton et al. 2002, Burton 2007). Still, waterbird disturbance remains poorly documented, which is surprising given the frequency at which it is cited as a threat. Furthermore, studies of waterbird disturbance have mainly occurred in the Northern Hemisphere and to-date no studies have attempted to assess the impacts of disturbance to waterbirds in tropical African wetlands.

Waterbirds: flagships for the rural poor

Waterbird conservation may seem unimportant to governments of developing countries which face more immediate and pressing issues such as poverty reduction, sanitation, health and education. However, the utilization of waterbirds as flagship species can enhance the protection of threatened wetlands and ensure the continued functioning of wetland services (Davidson and Stroud 2006). Species-based arguments alone are likely to have little impact on decision-making for wetland protection and sustainable development, and it is essential for scientists to communicate the importance of wetland conservation to policy-makers within government.

Heightened recognition of the need to integrate wetland conservation and sustainable development has arisen because of mounting evidence of the importance of wetlands to local livelihoods in Africa (Mwanza 2005). Wetlands generate economic value in the form of direct, indirect, and potential use (Lannas and Turpie 2009), yet poor planning continues to result in overexploitation and degradation of wetlands in many parts of Africa (OECD 1996). Solutions to this problem have not yet found their way into the formulation of public policy. In consequence, a lack of general knowledge regarding the ecological and socioeconomic importance of wetland ecosystems has resulted in poorly informed policies regarding their use and management (Smit and Wiseman 2001, Terer et al. 2004). Studies of the provisioning value of wetlands are few, and wetlands are increasingly overused and exploited under the auspices of economic development. The reality is that wetland drainage, conversion and overuse may provide short-term benefits to food and livelihood security but compromise the long-term sustainability of the benefits to communities (Dixon and Wood 2003).

Wetland loss represents the loss of unrealized benefits and often overlooked values, particularly as they pertain to the rural poor. The poorest and most disadvantaged people are also those most dependent upon natural resources for day-to-day survival (Wood 1997). In South Africa alone, millions of people depend upon natural resources for daily survival (Wynberg 2002). However the use of natural resources by rural Africans is often unregulated and can lead to overuse (Hockey and Bosman 1986, Hockey et al. 1988). Case studies of wetlands in rural Africa show that wetland loss is often driven by overuse caused by poverty and overpopulation (Mendelson and el Obeid 2003, Schuyt 2005). Wetlands provide food, water, and raw materials as well as services such as waste treatment, nurseries for fish, and flood water regulation (MEA 2005). In addition to generating income and providing services, wetlands provide the rural poor with opportunities to spread risk across a diversified livelihood (Lannas and Turpie 2009). Wetlands act further as safety nets against shocks such as drought or food shortage (Ratner et al. 2004). Therefore, sustainable management of wetlands is of paramount importance in areas where the rural poor depend on wetland goods and services for their livelihood, and should include regulations preventing overuse (Ratner et al. 2004).

Sustainable management and the Important Bird Area programme

Developing conservation activities for which people receive income-generating benefits can serve the dual purpose of preserving the goods and services proffered by wetlands and sustainable conservation of biodiversity. To this end, conservation planners increasingly seek opportunities to harmonize the needs of conservation and people, and embrace opportunities to integrate the local community into conservation planning (Cowling et al. 2009). BirdLife International's Africa NGO-Government Partnerships for Sustainable Biodiversity Action Programme recognizes the need to empower communities and facilitate the participation of local people in the management of biodiversity resources. Under this programme, BirdLife International has created partnerships with national NGOs in 18 African countries through which it undertakes education and leadership training, conservation activities, and sustainable development projects at Important Bird Areas (IBAs - Bennun and Njoroge 2001). The programme was implemented in ten participating countries (Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Sierra Leone, South Africa, Tanzania, Tunisia, and Uganda) between 1998 and 2000, and facilitated the development of site-support groups at 49 African IBAs (Fishpool and Evans 2001).

Adopted by African countries in 1993, the IBA programme is an international system designed by BirdLife International to identify, document, and advocate protection of critical sites for the global conservation of birds(Fishpool and Evans 2001). The criteria for designating wetland IBAs is based on criteria also used for the designation of internationally important wetlands under the RAMSAR Convention; however, only 11% of IBAs in Africa are protected by International Conventions. Fifty-six percent of IBAs in Africa are protected under national law, although enforcement of protection varies widely (Fishpool and Evans 2001).

Site-support groups comprise members of communities adjacent to IBAs and are provided training through the BirdLife Africa Partnerships Initiative. These groups regularly participate in conservation activities at IBAs, and implement income-generating conservation initiatives (e.g. bee-keeping, ecotourism). They also work with NGOs and governments to advocate monitoring and management of biodiversity resources in IBAs (Fishpool and Evans 2001).

Poor planning and unplanned developments create pressures on many of Africa's IBAs and location-specific approaches for conservation of African IBAs is needed. In Kenya, 40% of the 60 IBAs are located outside protected areas and face numerous threats from unregulated human activity (Bennun and Njoroge 2001). The majority of Kenya's rural population consists of agriculturalists, pastoralists and fishers whose livelihoods are heavily dependent upon natural resources (Kinyua 2004). With a population that increased rapidly from 8.2 million in the early 1960s to 38.8 million at present, and poverty levels of 48% (CIA 2010), there is a pressing need to manage natural resources sustainably in order to meet Millenium Development Goals for access to clean water, poverty reduction, and the conservation of biodiversity (UNDP 2003). Moreover, land allocation and conversion in Kenya is often performed without regard to relevant social and environmental factors, and often to the disadvantage of the rural poor. In the recent past, corruption in land ownership and land use has been widespread and the Constitution of Kenya (ratified in 2010) includes stipulations to redress these unfair land allocations. Therefore, the creation of community-based reserves on communal lands holds new promise in the future of the nation. Most current environmental regulations were adopted during the colonial era and do not facilitate the achievement of sustainable management through participatory and co-operative approaches (Norton-Griffiths 2000). Looking forward, however, the gazetting of additional land in the form of protected areas is unlikely, given the possibility of more pressing development concerns. Thus, opportunities for local-scale and community-based conservation should yet again be pursued as a matter of public policy (Fanshawe and Bennun 1991).

Despite considerable challenges at the national level, local conservation initiatives are increasingly successful. In particular, Kenya's site-support groups with the BirdLife Africa Partnership have initiated income-generating conservation activities at many IBAs (Bennun and Njoroge 2001). Successful programs include schemes which integrate ecotourism activities to generate funds for the conservation and sustainable management of resources at IBAs (e.g. Mida Creek, Arabuko-Sokoke Forest Reserve – Appendix A). However, sustainable management and development of ecotourism initiatives require research into the value of resources and pressures that may conflict with conservation goals on a local scale (Naidoo et al. 2006). These factors are poorly understood and poorly supported in East Africa.

Weighing the costs and benefits of conservation to local communities requires an understanding of how communities use resources in sites of conservation importance, and the unrealized value of those resources in terms of biodiversity, goods and services, and income-generating potential (Shackleton et al. 1998, Turpie 2000). These values can be made more explicit through the process of economic valuation (Schuyt 2005). Integrating economic valuation with ecological modelling can help to solve the problem of information failure and communicate the costs and benefits of conservation to governments and society (Turner et al. 2000). By integrating economic assessments with ecological research, scientists can inform policies regarding sustainable use of wetlands and the costs or benefits of regulating resource-extraction activities. Filling this gap in information can facilitate harmonization of subsistence activities and provide new knowledge regarding threats to wetlands and their biota.

A rapid assessment of conservation issues at a tropical African wetland

This study represents an integrated approach to filling information gaps and testing rapid techniques for assessing the costs and benefits of conservation in a rural African setting. The study is intended to contribute knowledge essential to a developing a strategic framework for conservation and development in an East African Important Bird Area and to establish a methodology which can be applied in other, similar study sites. This is achieved by:

1. Utilizing a technique to assess rapidly the impacts of localized human activity on waterbirds at communal lands.
2. Ascertaining the existing and potential value of wetland resources within an IBA.
3. Subsequently assessing the costs and benefits of implementing conservation action through regulatory or substitutive mechanisms.

Integrated ecological-economic research allows identification of possible conflicts between wetland users and biodiversity, and provides alternatives and substitutes for unsustainable practices (Turner et al. 2000). Furthermore, an understanding of the impacts of disturbance on waterbirds at specific locations will inform sound management of waterbird species at key sites (Nisbet 2000).

Study Area

Climate and vegetation

The Sabaki River Mouth IBA (3º09'39"S, 40º08'20"E) includes the estuary of the Athi catchment, where the Athi-Galani-Sabaki River meets the Indian Ocean on the south-central coast of Kenya (Appendix A). Sabaki estuary is an open-estuary system with an intertidal area consisting largely of mudflats, although sediment deposition rates are high and the substratum composition is dynamic (Brakel 1984). The size of the intertidal area varies seasonally, with dramatic variation in river flow between the wet season (April – July, discharge = 5000 $m^3 \bullet s^{-1}$) and the dry season (August – March, discharge = 20 $m^3 \bullet s^{-1}$ - Katwijk et al. 1993). The Sabaki estuary is located in Malindi District of the Coast Province and is characterized by a tropical climate with south-easterly trade winds prevailing from April to October and north-easterly monsoon winds from November to March (Abuodha 1998). Adjacent to the mudflats are sandbanks and dunes up to 40 m in height. On the periphery of the mudflats are mangrove stands dominated by *Avicennia marina, Brugiera gymnorhiza* and *Rhizophora mucronat*. Beyond the intertidal area is scrubland dominated by *Acacia* spp. The native bush is severely denuded due to excessive fuelwood collection and charcoal burning (pers. obs.). Alien plant species, including the highly invasive shrub *Prosopis juliflora,* are common throughout the agricultural, residential, and scrubland areas. Although this area is not formally protected, the local community of Sabaki and national law have prevented commercial development from occurring in the riparian area.

Avifauna

Sabaki River Mouth IBA is one of Kenya's 60 Important Bird Areas (Fishpool and Evans 2001). A total of 186 bird species, including 91 species of waterbirds, have been recorded in the 250 ha of intertidal mudflats and adjacent scrubland and agricultural fields (Valle and Jackson 2009). The estuary achieved Important Bird Area status under the criterion for 'congregations', whereby it hosts more than 1% of the biogeographic population of Sooty Gull *Larus hemprichii*, Saunders's Tern *Sternula saundersi*, and Lesser Crested Tern *Thalasseus bengalensis* (Nasirwa et al. 1995). Significant numbers of terns and gulls use the estuary as a night-time roost, with up to 500 000 birds being counted at low tide in the 100 ha intertidal area (C. Jackson, unpubl. data). The estuary hosts large numbers of waders which feed on macro-invertebrates and plant matter on the tidal flats (Seys et al. 1995). Palearctic-breeding migrant Curlew Sandpiper *Calidris ferruginea*, Common Ringed Plover *Charadrius hiaticula* and Little Stint *Calidris minuta* occur on the intertidal mudflats in flocks numbering greater than 500 birds during migration and over-wintering periods (C. Jackson upubl. data). Broad-billed Sandpipers *Limicola falcinellus* have been recorded in their largest numbers in

East Africa at the estuary, and use the area both as a migratory stop-over and wintering ground (Britton and Britton 1973). Non-breeding White-fronted Plovers *Charadrius marginatus* and Lesser Flamingos *Phoeniconaias minor* are resident year-round and Greater Flamingos *Phoenicopterus roseus* occur throughout the northern winter months. Lesser Sand Plovers *Charadrius mongolus* are present during migration and over-winter on the tidal flats. Greater Sand Plovers *Charadrius leschenaultii* are present in smaller numbers than Lesser Sand Plovers, preferring less silty habitats (Seys et al. 1995). Hereafter, refer to Appendix B for scientific names of waterbirds. Of six major wetlands on the Kenyan coast included in bird counts, the Sabaki River Mouth supports the highest avian species richness (Seys et al. 1995). The estuary also hosts the highest number of waterbird species that feed on benthic invertebrates, reflecting the high densities of the latter in the estuary (Houte-Hayes 2005).

Estuary use and conservation

Humans settled adjacent to the Sabaki estuary in 1918 when the Giriama tribe began small-scale agriculture in the area which is now known as Sabaki Village (3º08'55" S, 40º07'32." E). Sabaki Village is 5 km north of Malindi on the north side of the Sabaki River, with a population of just more than 2000 people. Neighbouring communities within 2 km of the intertidal area include the village of Masheheni, also believed to have been settled in the 1910s, and a squatter community which settled in the past decade on land on the south side of the river tenured by the Department of Livestock. Three major famines have occurred in the Sabaki community in the 20th Century: between 1941–1945, in the early 1960s, and during major droughts experienced in Kenya in the early 1990s (E. Utumbi unpubl. data). The majority of the community adjacent to the estuary lives in poverty and secondary education levels are low (Koskela and Ruuska2009). Conservation activities at Sabaki have taken place amongst local residents and NGOs in the area, but the Kenyan government has not engaged in active community conservation of the estuary. Several subsistence activities take place in the estuary including water collection, livestock watering, fishing, and crustacean/gastropod collection. Areas adjacent to the estuary and within the boundaries of the IBA are used for fuelwood collection, charcoal burning, water abstraction, livestock grazing, small-scale agriculture, and collection of raw materials and medicinal plants. Resource extraction, fisheries, and farming activities are unregulated and their contribution to local livelihoods at Sabaki has not previously been quantified.

The estuary is a tourist attraction for its bird life, striking landscape, and a small resident population of Hippopotamuses *Hippopotamus amphibius* (about 18 individuals estimated in 2010). Birdwatchers have visited the Sabaki for decades to view the large congregations of waterbirds and local school groups also visit the estuary. There is no tourism infrastructure and tourism activities are unregulated. The Sabaki River Estuary Youth Group is the official BirdLife site support group, formed in 2000, and promotes ecotourism and community conservation of the estuary (M. Kadenge, pers. comm.). Workshops and meetings are held frequently, community-based bee-keeping has been implemented, and two NGOs (A Rocha Kenya and NatureKenya) are actively involved in conservation activities at the estuary. However, conservation at the site remains in its infancy and the community has yet to derive substantial benefits from conservation activities.

CHAPTER 2. Human disturbance of intertidally foraging waterbirds in the Sabaki estuary

INTRODUCTION

In coastal East Africa, intertidal mudflats of tropical estuaries are feeding and roosting areas for internationally-important numbers of migrant waterbirds. Human population growth, poverty and loss of terrestrial wetlands have led to intense use and associated degradation of wetlands throughout Africa (Moser et al. 1996, Dixon and Wood 2003, Schuyt 2005). This, combined with increased tourism, contentions over land-claims, agricultural expansion and overexploitation of fisheries, has drawn attention to the conservation implications of elevated disturbance levels on estuarine waterbirds (Davidson and Rothwell 1993, Hill et al. 1997). Excessive disturbance from human activity may reduce foraging efficiency or waterbird numbers in key staging and wintering sites (Knapton et al. 2000), but few studies have quantified these impacts. Most studies have focused on the immediate effects of disturbance, drawing inference from local effects to predict impacts at the population level (Gill et al. 1996, Hill et al. 1997, Gill et al. 2001).

Waterbird disturbance research is mainly undertaken in the Northern Hemisphere or at temperate latitudes and few studies have taken place at wetlands used by impoverished rural communities (Quan et al. 2002). Prior to this study, disturbance of waterbirds on tropical African wetlands has not been quantified. Location-specific research is needed to identify factors causing disturbance and to evaluate the interspecific vulnerability of waterbirds to such disturbance (Nisbet 2000). Funding for research to guide conservation of wetland birds in East Africa is limited, and surrogate measures are needed to assess vulnerability of waterbirds and subsequently implement knowledge-based management. To this end, developing affordable and rapid techniques for monitoring waterbird disturbance should be prioritized.

Disturbance is an ill-defined concept in ecology but, for the purposes of this study, is treated as a discrete event which alters the behaviour of a bird relative to its behaviour in the absence of such an event. Thus, human disturbance is the action of a human or commensal (e.g. cattle) which causes a simultaneous response in a bird's behaviour. Disturbance of breeding birds may lead to stress-induced emigration or reduced reproductive output from populations of birds who forego breeding as a result of disturbance (Reijnen et al. 1997). This study examines a similar, related phenomenon whose effects are more subtle, viz the impacts of disturbance on nutrient acquisition by estuarine birds. In estuaries, disturbance effects may manifest by altering the behaviour of birds feeding and resting on water, feeding on tidal flats, or roosting at high tide (Davidson and Rothwell 1993). The magnitude of disturbance effects will be greatest when nutrient acquisition is compromised as a result of disturbance events (Cayford 1993). Studies of disturbance impacts on birds feeding on tidal flats are pertinent as these individuals already experience limited foraging opportunities due to the physical extent and limited temporal availability of tidal flats (Goss-Custard 1985).

In the absence of disturbance, wader densities have been assumed to accord to an “ideal free distribution” where predator densities correspond to prey densities and tend to be higher in preferred feeding areas (Goss-Custard 1970). The “ideal despotic distribution” is a modification of the former which recognizes that individuals will compete for the best areas to maximize intake rate (Fretwell and Lucas 1970). However, the dispersion of waders will also depend upon territoriality of individuals. Territoriality in waders is variable both among species and locations (Colwell 2000), but will influence the response of individuals to a disturbance. For non-territorial individuals, intake rates should be similar between sites due to a balance between prey densities and interference competition between birds. For territorial individuals, intake rates will vary as some birds will be less successful at holding territories and thus gain access to sites of variable foraging potential. If waders are forced to flee an area in response to disturbance, dispersion patterns will be altered, resulting in artificially high bird densities at some areas or birds moving into sub-optimal areas (Goss-Custard 1980). Increased competition, aggression from conspecifics holding territories, or depletion of prey may lead to reduced intake rates of birds in areas with higher than normal densities resulting from disturbance in adjacent areas (Goss-Custard 1980, Sutherland and Parker 1992). Thus, the response of birds to disturbance and the impact of disturbance on individuals will depend on prey availability and territoriality of birds in the same region.

The impact of disturbance depends upon the magnitude and duration of disturbance events. Brief disturbances can result in birds being temporarily deprived of feeding habitat or foraging opportunities (Smith and Visser 1993); excessive or sustained disturbance may cause changes in distribution, abundance, and feeding site selection (Kahl 1991), and equate to loss of habitat in of otherwise suitable feeding areas (Cayford 1993, Knapton et al. 2000). By interfering with feeding behaviour, disturbance has the potential to reduce the ability of waterbirds to acquire sufficient resources to sustain over-winter survival and subsequent migration (Haramis et al. 1986). If intake rates are reduced and body condition is affected, individual survival can become compromised by the effects of disturbance (Owen 1993).

Measuring behavioural responses to disturbance makes it possible to infer relative susceptibility of species based on the magnitude of their responses to disturbance stimuli. The manner in which birds respond to disturbance influences the resulting impacts (if any) on foraging efficiency (Belanger and Bedard 1989). A bird which is susceptible to the negative effects of disturbance should take flight at long distances from disturbance and take longer to return once the disturbance has passed. Less susceptible birds will take flight at shorter distances from disturbance and return more quickly to optimal feeding areas following a disturbance. This anticipated range of responses makes it possible to place species along an impact gradient. In this way, we can identify species that are prone to lose more foraging opportunities as a result of disturbance (Owen 1993). If we can identify those species that are the most vulnerable to the effects of disturbance, this has the potential to assist in conservation planning (Hill et al. 1997). Evaluating the vulnerability of species to disturbance must be coupled with research regarding the adaptive responses of species to disturbance. For example, birds may reduce the effects of disturbance by habituating to disturbance (Nisbet 2000, Baudains and Lloyd 2007) or increasing food intake when disturbance is absent (Dugan 1981, Swennen et al. 1989).

Empirical evidence demonstrating population-level impacts of disturbance is elusive for two reasons - firstly, the difficulty of isolating key variables governing waterbird dispersion; and secondly, the difficulty in separating the short-term effects of single disturbance events relative to longer term responses to persistent disturbance pressures (Cayford 1993, Hill et al. 1997). Models for predicting the reduction in the potential of estuaries to host waterbirds, and assessing how much of that reduced potential is due to disturbance, require rigorous collection of key variables related to bird density and are often unrealistic or impossible to obtain (Cayford 1993). For these reasons, few studies have examined the effects of disturbance on waterbirds at the flyway or population level. Despite the difficulty of quantifying the impacts of disturbance, sustained reductions in foraging performance due to disturbance may effectively reduce habitat quality at key sites for waterbirds and cannot be ignored.

The Sabaki River Mouth IBA includes the estuary formed by the second-longest river in Kenya where it meets the Indian Ocean and is host to globally significant numbers of roosting seabirds and foraging waders (Seys et al. 1995, Fishpool and Evans 2001, Valle and Jackson 2009). Palearctic-breeding migrants utilize the intertidal area as a stop-over site and wintering area, and non-breeding individuals (mostly juveniles) spend the boreal summer here (Seys et al. 1995). During southward passage in September – October, substantial numbers of terns and wading birds use the intertidal area for both roosting and foraging, respectively (Nasirwa et al. 1995, Valle and Jackson 2009). Rapid habitat change has occurred in Sabaki in recent decades due to frequent and severe deposition of sediment loads (Brakel 1984, Sabaki River Estuary Youth Group pers. comm.). Although the area is not formally protected, the local community of Sabaki and land protection entrenched in Kenyan law have prevented commercial development in the riparian area. Recreational users include tourists and bird-watchers, and subsistence users include fishermen, crustacean/gastropod collectors, and herders with cattle or goats that graze on the river bank and traverse the intertidal flats to drink from the river (see Chapter 3).

To evaluate the effects of human activity on waterbird dispersion, this study uses basic information gathered on human activity, waterbird dispersion, and behavioural responses of waterbirds to experimental disturbance. The study also presents a rapid and affordable technique for assessing species-specific vulnerability of foraging waterbirds to disturbance at an East African IBA, where time and funds are a rare luxury.

METHODS

Intertidal distribution of humans and livestock

To quantify human and waterbird densities in the estuary, from the river mouth to 1500 m upstream, the intertidal area and adjacent sandy areas were divided into 10 blocks and 3 blocks, respectively (Figure 2.1). Blocks were demarcated by habitat features or wooden stakes. Estimates of block area were made by walking GPS tracks at the perimeters of blocks, creating a polygon for each block in ArcView GIS 3.3, and obtaining estimates of area in hectares for each block from resultant geo-referenced maps. To estimate the area of intertidal mudflats at low tide, estimates for percentage river cover were made on the neap-tide cycle (estimated concurrently with waterbird counts) and the proportion of block area taken up by running river water was subtracted from estimates of total block area.

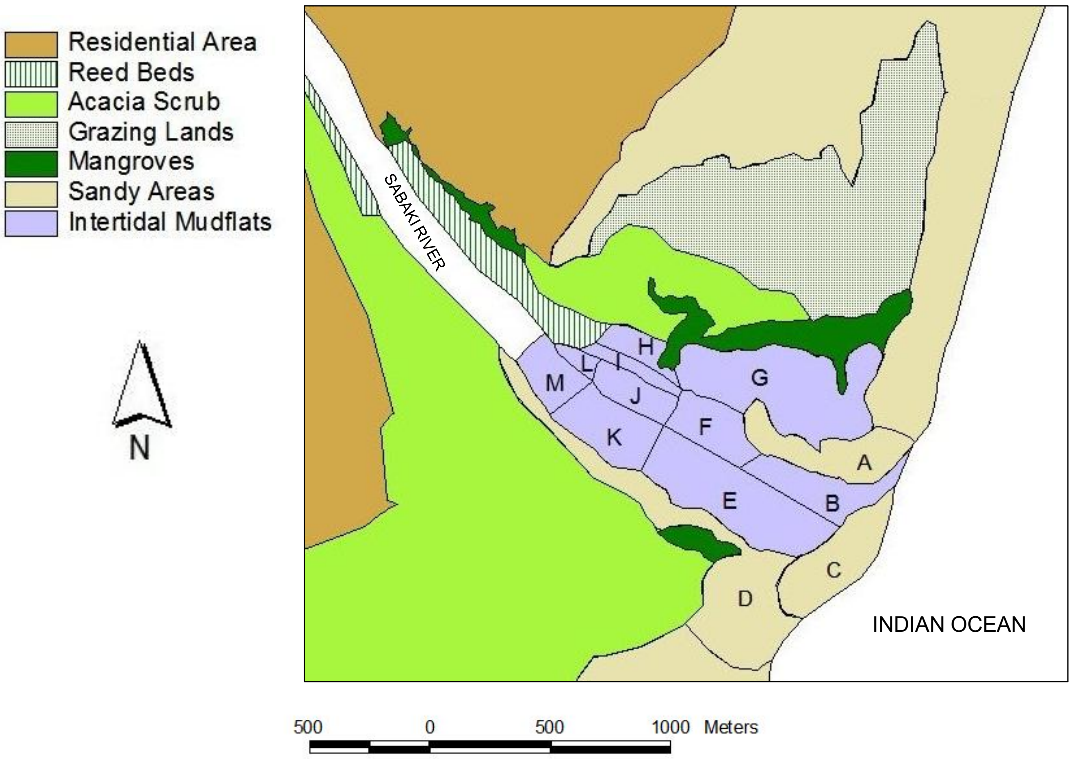

Figure 2.1. The intertidal and adjacent areas of Sabaki estuary where waterbird counts were conducted in the intertidal habitat blocks indicated in blue (B, E – M), and scans for human activity were conducted both in intertidal blocks and on the three sandy area blocks (A, C, and D).

From 20 October to 25 November 2010 surveys of human and livestock activity were conducted in the 13 blocks over a 4-hour period spanning low tide. Data recorded included the number of individuals, user type, and whether individuals were stationary or moving. Users were classified as fishers, beach boys (typically defined in Kenya as males under 35 years of age hawking services or wares on the beach), crab collectors, water collectors, herders, tourists, cattle or goats. Classification of user types was based on their activity at the time of observation and beach boys were differentiated from visitors by the research assistant who was a regular fisher at the estuary and familiar with local users. During each survey, four scans were performed every 30 min around low tide, starting 45 min before low tide. Scans were performed on both the spring and neap tide cycles. Each block was surveyed twice for each day of the week (Monday through Sunday, N = 14) to capture variation in disturbance levels which occurred over week-days.

An average number of disturbance events (each individual representing an event) was calculated for each site to measure the distribution of disturbance in the estuary. Mean numbers of disturbers were divided by the total area scanned per survey to obtain mean densities of individuals. A MANOVA was used to compare densities of potential disturbance events (human and livestock) between habitat blocks for all disturbance types pooled and subsequently with each user-type as a factor in the model. For user-types whose densities were significantly different between habitat blocks, their distribution was mapped to show the distribution of disturbance events across the estuary.

Intertidal waterbird distribution

From 28 September through 22 November 2010, waterbird counts were conducted in the 10 intertidal blocks in a 4-hour period spanning low tide on the neap tide cycle. Minimal areas of intertidal mudflats are exposed during the neap tide cycle, thus birds will appear more concentrated, allowing greater accuracy of count data. The aim was to obtain densities of waterbirds in a disturbance-free state (i.e. in the absence of humans or livestock within 100 m of block perimeters). In a system such as the Sabaki estuary, where human or livestock disturbances are sustained and widespread, it is difficult to control for the impacts on bird densities from disturbances occurring in adjacent blocks. Therefore, each block was counted four times to ascertain mean waterbird densities, in efforts to reduce problems associated with disturbance effects at the estuary-wide scale.

Estimating waterbird densities in the three sandy areas (Figure 2.1) was impossible due to high human densities in these areas at low tide. Observers were situated at distances greater than 100 m from blocks. Each block was counted four times during the neap tide cycle (2 cycles), on days one previous or following lowest tidal levels. Tidal calendars were obtained from Tide Calendars for Malindi (Mobile Geographics 2010). Scans were conducted with a 30x Leica telescope.

To estimate expected waterbird densities in the absence of disturbance, bird densities were calculated for each block by pooling bird abundance for: 1. all species, 2. foraging species, and 3.

roosting species, and dividing by the area of intertidal mudflat in each block at neap low tide. Per block densities were tested for evenness across the estuary using MANOVA. Density data were not normally distributed, so were log-transformed to meet the assumptions of tests (Kolmogorov-Smirnov: K-S = 0.101, df = 50, p = 0.200). Regressions were performed to test for the existence of autocorrelations or co-regulatory relationships between bird and human densities. All statistical analysis was performed with Microsoft Excel (Microsoft 2007) and SPSS v. 18.0 (IBM SPSS Inc. 2010).

Waterbird response to human disturbance

This study used a three-pronged approach to quantify responses of waterbirds to human disturbance. This was done by i) estimating minimum approach distances of birds to a stationary disturbance (SD) , ii) mean density of birds within a 40 m radius of disturbance (D40), and iii) the time taken for localized bird abundance to recover to 90% (TR_{90}) of original numbers after birds fled a mobile disturbance. Values for minimum distance of birds from disturbance, the density of birds in disturbed plots, and TR_{90} were calculated separately for each species. SD and D40 estimates were collected simultaneously in stationary disturbance plots, and TR_{90} values were obtained by conducting recovery-time (RT) experiments. For all these experiments, disturbances were simulated at random sites on the intertidal mudflats. Waypoints were overlaid on the intertidal area using the "Create Random Points" function in ArcView GIS 3.3, and, after ground-truthing, plots were selected based on the presence of a uniform substratum type within a circle of 40 m radius for SD and D40 experiments (N = 20) and 50 x 20 m plots for RT experiments (N = 15). The size of plots was determined based on the ability of observers to census the entire plot in 5-minute and 2-minute intervals, respectively.

For stationary disturbance experiments, each plot was demarcated with stakes at 15 m and 30 m from the centre of the plot to assist the observer in estimating distances of waterbirds from the point of disturbance. RT plots were demarcated by stakes at the four corners of rectangular plots. Stakes were positioned at least three days before the experimental disturbance to allow birds time to habituate. To ensure that the observer did not act as an additional source of disturbance, observations were made at a distance of 150 - 200 m from the simulated disturbance plot. Only those experiments where extrinsic disturbance (i.e other human activity or a raptor disturbance) did not occur within 200 m of the experimental plot during the observation periods were included in analyses.

Disturbances were simulated in SD plots by a "disturber" walking to the centre of the plot and performing activities typical of stationary fishermen and crab collectors. These activities included digging into the substratum, and simulating the activity of pulling fish from or fixing holes in fishing nets. “Disturbers” were equipped with a gill net typical of the nets used by local fishermen in the estuary (70 mm mesh, 80 m length, and a wooden stake of approximately 2 m length at each end of the net). Disturbances were simulated for five minutes before the observation period of 15 minutes. Three scans were conducted at five-minute intervals during which the number of individuals of each waterbird species and estimated distance of individuals from the disturbance source were recorded within a 40 m radius of the disturber.

The time required for bird numbers to recover to 90% of their pre-disturbance numbers (TR_{90}) following a mobile disturbance was quantified in RT experiments (Figure 2.2). Time to recover 90% was used rather than time to recover to 100% of pre-disturbance numbers because birds may return locally but not to identical micro-sites. All birds within RT plots were counted before simulating a disturbance. The “disturber” would walk directly from the observer to the centre of the plot, causing all birds to flee the plot area. A voice recorder was used to document post-disturbance abundance of birds at 0, 0.5 min, and 1 min following the disturbance, and thereafter every two minutes up to 15 minutes following disturbance.

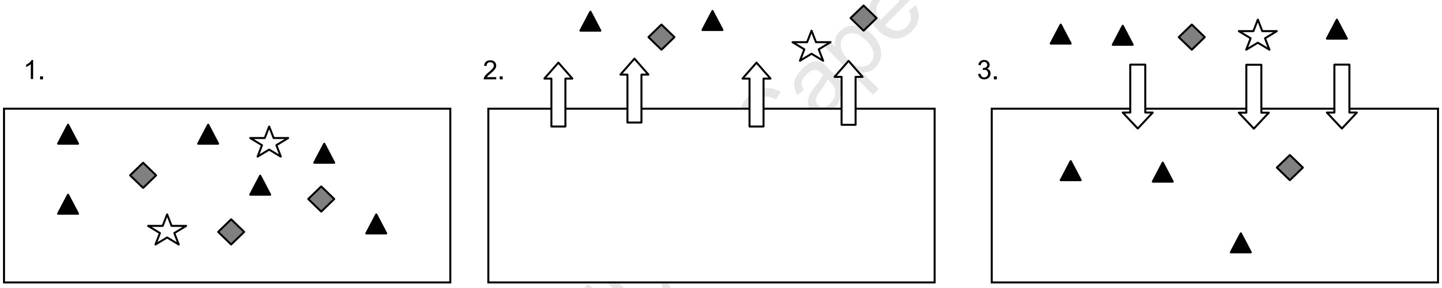

Figure 2.2. Recovery time (RT) experiments conducted in Sabaki estuary where the box represents a 50 x 20 m plot and the sequence of events for each experiment are: 1. All waterbirds counted prior to disturbance. 2. Mobile disturbance simulated by walking through plot causing all birds to flee. 3. Waterbird abundances within plot recorded at 0 – 0.5 min, 0.5- 1 min, and 2 min intervals for 15 minutes following disturbance.

Data analysis

Expected waterbird densities should vary among habitat blocks due to inter-specific differences in habitat requirements and differences in substratum, salinity and prey availability. For this reason I calculated species-specific minimum distance from disturbance and density within SD plots for each habitat block. Estimates for minimum distance from disturbance were taken as the minimum approach distance observed for each focal species over two trials within blocks. To assess the effect of experimental disturbance on waterbird dispersion, the mean density of birds within a 40 m radius of stationary disturbances (D40) was estimated from the mean abundance of birds over three scans (at 5 min intervals) per experiment and divided by the area of plots (0.5027 ha). Species which occurred on the mudflats at mean densities < 0.5 individuals/ha were excluded from analyses because of the low probability of detecting these species in disturbance plots. Further, species for which only one individual was observed within SD plots in any one habitat block were excluded from analyses.

Minimum approach distances and mean densities in SD plots were regressed against mean density for each intertidal habitat block (Appendix C, D). The resulting regression lines approximated a mean relationship between expected intertidal waterbird densities (based on per-block censuses) and i) minimum approach distances and ii) densities in SD plots. The resultant regressions represent an average response (in terms of density and distance, respectively) to disturbance across focal species. Appendices C and D each show an example of one of these regressions from one of six habitat blocks in which disturbance experiments were conducted. Expected values for distance and density (E) were estimated from these regression lines and normalized mean residuals were obtained by calculating a relative deviance of observed approach distance and densities (O) from expected approach distances and densities (O-E)/E, Hockey and Wilson 2003). By incorporating the apparent mathematical response of species exhibiting different distribution patterns across an average, the residual provides the researcher with a relative deviation of each species from the average response to disturbance, These residuals represent a metric for the relative magnitude of response to disturbance for each species. The residuals for minimum approach distance were multiplied by -1, because the expected relationship between proximity and density is inherently negative. Standardizing the residuals in this way allowed expression of a strong response as negative for both SD metrics. Average residuals were calculated for each species from the residuals for distance and density across blocks (N = 6). Ninety-five percent confidence intervals were calculated from species-specific density and distance metrics for each habitat block.

TR_{90} after a mobile disturbance was obtained for each species by calculating the mean proportion of pre-disturbance abundances at each post-disturbance time interval. The time after which the mean proportion of original bird abundance was equal to or greater than 0.90 was taken as the TR_{90} for each focal species. As an example, Appendix E depicts mean proportional abundance over time following disturbance for Common Ringed Plovers.

In summary, therefore, three different disturbance metrics were calculated: 1) the approach distance residual (negative residuals indicating strong avoidance of disturbance); 2) the density residual (deviance of observed disturbance densities relative to densities in the absence of disturbance); and 3) the time taken for post-disturbance densities to recover to 90% of pre-disturbance levels.

A semi-quantitative model was developed to compare the three disturbance metrics based on a risk-assessment methodology developed by Bond (1995) and refined by Hockey and Curtis (2008). This model entailed plotting normalized mean residuals for density and distance responses against each other and superimposing the TR_{90} (indicated by dots of differing sizes). If the techniques employed for measuring disturbance response are in agreement, then species should be characterised either by paired negative or paired positive residuals, and appear along a gradient from weak to strong responses. The hypothetical gradient of increasing magnitude of response to disturbance is based on how many birds of each species remain around a disturbance, how close birds will approach a disturbance, and how quickly birds recover following a disturbance. Because the gradient is scaled relatively, values for residuals would differ given a different suite of species, and do not represent the absolute numerical responses of each species to disturbance. Axes lengths were based on the largest observed residual value on each axis (Hockey and Curtis 2009). The third response variable (TR_{90}) was superimposed on this plot simply by representing increasing recovery times with increasingly large symbols (Figure 2.3). Response metrics were considered genuinely weak or strong for those average mean residuals with 95% confidence intervals which were bounded within negative or within positive quadrants of the model. Concordance between metrics was evaluated by examining whether average response indices for both density and distance lay within the top right or bottom left-hand corner of the model. Those values which showed concordance between metrics and significance of at least one metric were considered genuinely weak or strong responses to disturbance. Concordance between distance and density metrics with TR_{90} was evaluated by comparing the three metrics across each species. If the density and distance metrics are concordant with TR_{90}, we would expect that those species exhibiting weak responses to disturbance will also return more quickly following a disturbance. A hypothetical distribution is shown in Figure 2.3, where five species accorded nearly perfectly along a gradient from strong to average to weak responses to disturbance.

Information regarding flocking behaviour and territoriality was gathered based on personal observations over the course of the study and from Colwell (2000); and foraging tactics of individual waders taken from Hockey and Douie (1995). To assess conservation implications of disturbance impacts on focal species, information regarding population trends in the West Eurasian-East African Flyway was taken from Wetlands International (2010) and population trends at Sabaki were derived from annual waterbird counts conducted at Sabaki River Mouth from 2000 through 2010 (C. Jackson unpubl.data).

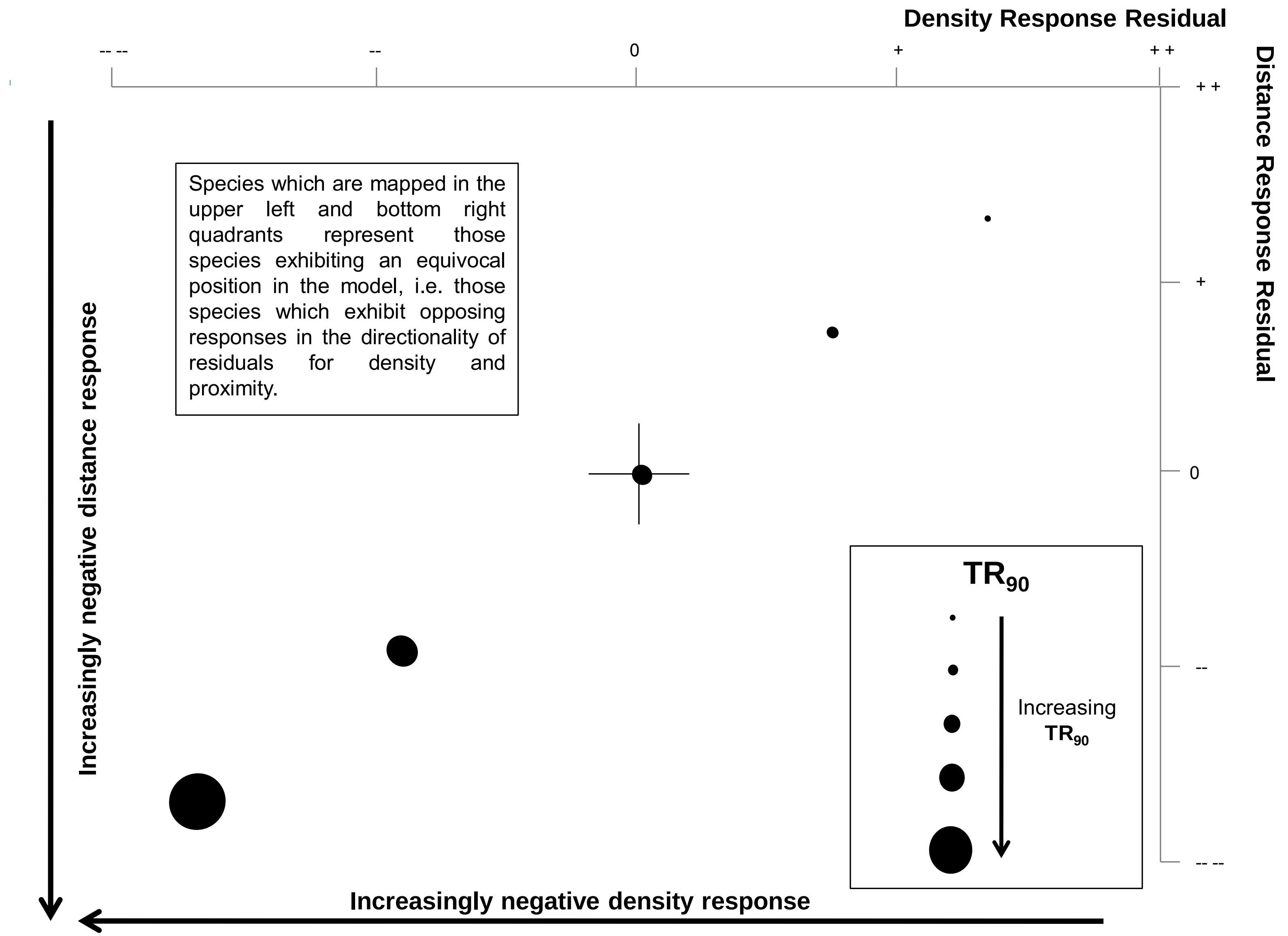

Figure 2.3. Hypothetical model used for mapping waterbirds according to relative differences in their magnitude of response to disturbance. Adapted from extinction risk models (Bond 1995, Hockey and Curtis 2009) for basic data collected on disturbance response of waterbirds on intertidal mudflats at Sabaki estuary.The placement of each dot represents the average relative response for a species and increasing sizes of dots indicate increasing post-disturbance recovery times (TR_{90}).

RESULTS

Intertidal dispersion of humans, livestock, and waterbirds

The total area surveyed for human activity was 100 ha of intertidal and sandy area habitat (Figure 2.1). Humans (besides observers) were always present in the estuary during low-tide scans. Anthropogenic activity in the study area comprise (in ranked order from highest abundance) cattle, fishers, tourists, goats, walkers, beach boys, crab collectors, bathers, fish buyers, herders, fuelwood collectors and launderers at any given time during the 4-hour survey period at low tide (Table 2.1). The majority of individuals were moving at the time of observation (64.4% of observations). The intensity (disturbers/ha) of potential disturbance events (humans and livestock pooled) differed significantly between blocks (MANOVA: $F = 3.023$, $df = 182$, $p = 0.008$), and more detailed multivariate analysis revealed that differences existed in density of disturbances between blocks depending on the user type (Table 2.1). The distribution of user-types whose densities were significantly different between blocks are shown in Appendix F and discussed further in Chapter 3. Overall, disturbance was widespread and continuous in the intertidal and adjacent areas from multiple user-types seeking different resources.

There was no significant relationship between human and livestock densities (pooled) and bird densities across the intertidal blocks (Figure 2.4, Linear Regression: $F = 2.33$, $df = 1, 9$, $p = 0.281$).

Table 2.1. The mean abundance (± SD) of each user type over the study area including the intertidal mudflats and sandy areas in Sabaki estuary, with results of a General Linear Model (df = 13, 162) used to identify non-random distributions of different user-types across the study area.

Disturbance Type	Mean Abundance	F (density)	p
Cattle	26.2 ± 6.8	1.969	0.026*
Fishers	13.2 ± 1.1	5.570	<0.001*
Tourist	4.6 ± 2.4	2.381	0.006*
Goats	1.2 ± 1	1.691	0.067
Walker	0.8 ± 0.3	1.428	0.151
Beach Boys	0.5 ± 0.2	1.921	0.031*
Crab Collector	0.4 ± 0.3	0.816	0.642
Bather	0.4 ± 0.2	1.276	0.232
Fish Buyer	0.4 ± 0.2	0.661	0.798
Herder	0.3 ± 0.1	1.542	0.107
Fuelwood	0.1 ± 0.1	0.882	0.573
Laundry	0.0 ± 0.0	0.658	0.801

* = p values <0.05

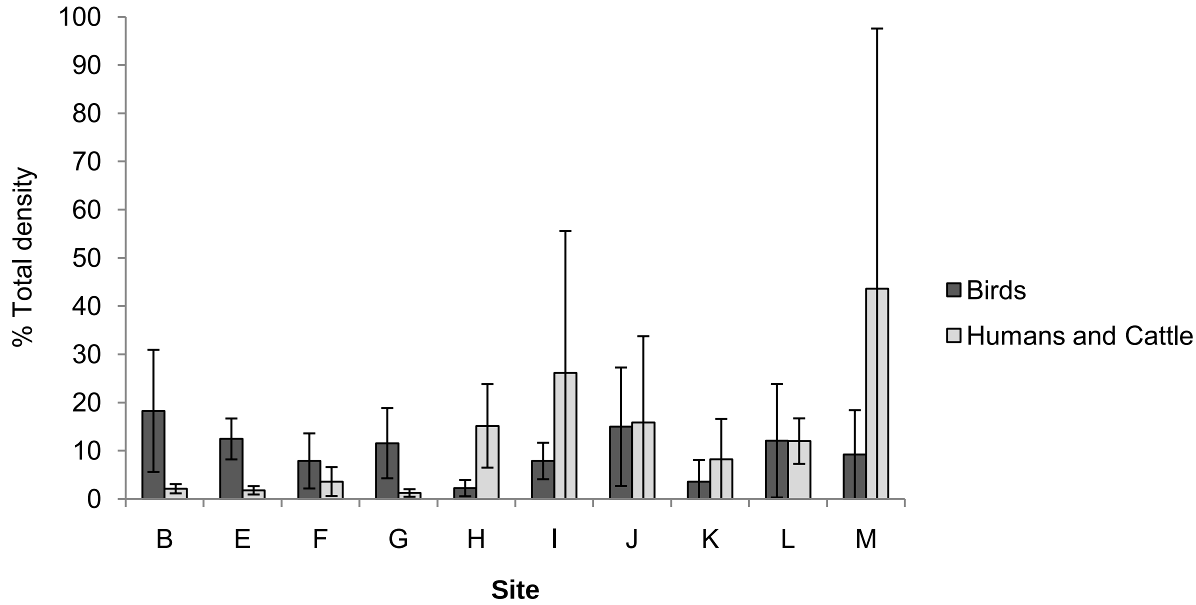

Figure 2.4. Comparison of the proportions of total intertidal densities of waterbirds and humans and cattle occurring in each of the 10 intertidal blocks at Sabaki River Mouth, with error bars indicating ±1 standard deviation.

The total intertidal area censused for waterbird densities (blocks B, E – M in Figure 2.1) was 63 ha, of which an estimated 37 ha was exposed substratum (sand, mud, or mixed sand and mud) at low tide on the neap tide cycle. Seventy-one waterbird species were observed during counts in the intertidal area (Appendix B). For subsequent analysis, species were separated into those using the intertidal region for foraging and roosting. The overall average density of foraging waterbirds at low tide was 115.0±20.5 birds/ha. The overall average density of roosting birds was 20.5±5.8 birds/ha, of these the majority were pelagic gulls and terns which roost in the intertidal area between foraging trips. Densities of foraging species differed significantly among blocks (MANOVA: $F = 2.994$, $df = 10, 40$, $p = 0.007$). Densities of roosting species were, however, not significantly different between blocks (MANOVA: $F = 2.181$, $df = 10, 40$, $p = 0.332$). Figure 2.5 shows the mean density of all foraging waterbird species measured in the intertidal habitat blocks from 28 September through 22 November 2010. Foraging birds congregated at their highest densities on the north bank of the river on a large tidal mudflat close to the river mouth (Figure 2.5, block G), and a smaller mudflat of similar substratum further from the river mouth (Figure 2.5, block L). Blocks with the lowest density of birds also contained the highest mean densities of cattle and tourists (Appendix F).

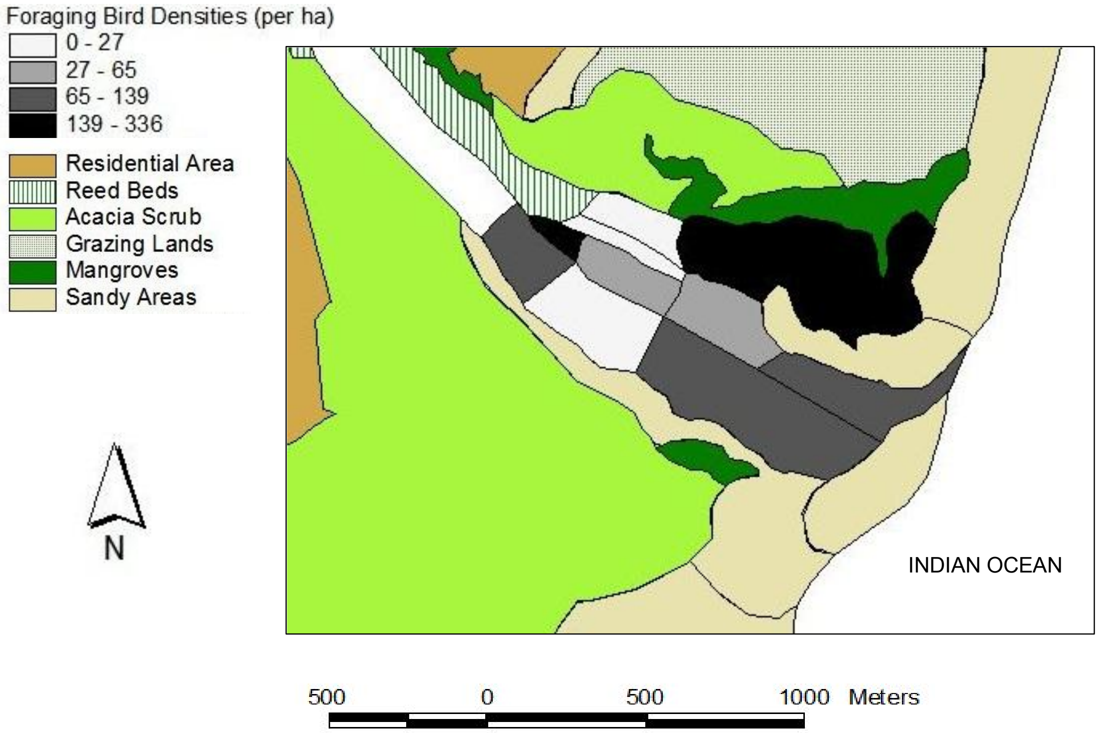

Figure 2.5. Mean foraging densities of waterbirds in the intertidal area of Sabaki estuary, obtained from per-block counts (N = 4) on the neap tide cycle, between 28 September and 22 November 2010.

Species occurring at highest average foraging densities (>2 individuals per ha) in the intertidal area were (in descending order of density) Curlew Sandpiper, Little Stint, Common Ringed Plover, Lesser Sand Plover, Greater Flamingo, and Greater Sand Plover (Appendix B). Bird species occurring at highest average roosting densities (>2 individuals per ha) in the intertidal area at low tide were (in descending order of density) Lesser Crested Tern, Sooty Gull, White-faced Duck and Common Tern (Appendix B).

Waterbird responses to human disturbance

Mean expected abundance (±1 standard error) of waterbirds in a randomly positioned circular plot of 40 m radius was 2.4 ± 0.6 individuals. Mean observed bird abundance in SD plots was lower, at 1.0 ± 0.6 individuals, although abundances varied among blocks. Mean minimum approach distance was not significantly related to mean density in the absence of disturbance in any habitat blocks (regressions $p > 0.05$). This supports our choice of model because multiple species respond differently to disturbance, and thus the relationship between approach distance and density is an ecological and not a mathematical one. . Mean minimum approach distances are presented for 14 focal species in Appendix G.

Maximum axis values for the vulnerability space diagram (Figure 2.3) were based on indices of proximity and density for Greater Flamingo and Terek Sandpiper, respectively (Table 2.2). Few species exhibited strikingly weak responses to disturbance, the weakest being Common Ringed Plovers and Broad-billed Sandpipers (Figure 2.6). There was concordance between disturbance and distance responses for all species but Marsh Sandpiper, which exhibited a negative response in density, but a marginally positive distance response (Figure 2.6, Table 2.3). Little Stint, Grey Plover, and Marsh Sandpiper, while exhibiting extreme density responses (strong, weak), had low response indices for proximity. This means that their response to disturbance is somewhat ambiguous. Species exhibiting the strongest response indices had TR_{90} values of more than 15 minutes, indicating not only a strong spatial response to stationary disturbance, but also slow recovery following mobile disturbance.

The responses in which the greatest confidence can be placed are of those species which lie furthest from the axes in the model (Figure 2.6), have lowest SDs, and exhibit concordance between stationary disturbance response metrics and TR_{90} (Table 2.2). These are exemplified by Lesser Flamingos, Greater Flamingos and Terek Sandpipers (all of which exhibited strong avoidance responses) and Common Ringed Plovers which exhibits a comparatively weak avoidance response (Figure 2.6, Table 2.2).

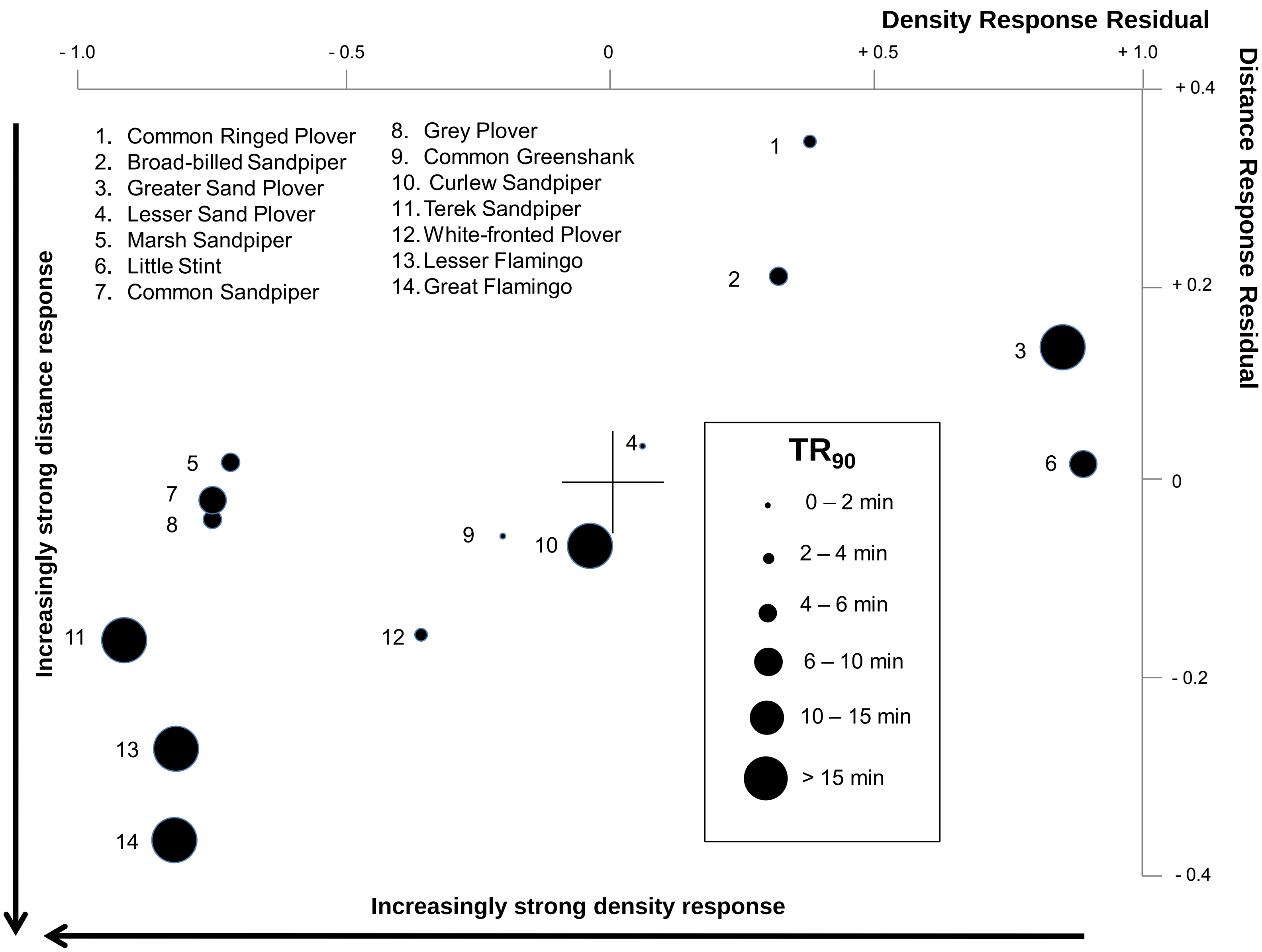

Figure 2.6. Map of fourteen focal waterbird species along a gradient of response to disturbance in the intertidal area of Sabaki estuary. Density and proximity response indices are residuals derived from observed densities within 40 m proximity of disturbances (D40) and minimum approach distance to stationary disturbances (SD) regressed against densities measured in the absence of disturbance, respectively. TR_{90} is the mean time interval following a disturbance at which birds recover 90% of their original abundances following a mobile human disturbance, indicated by the size of the symbol for each species.

Table 2.2. Average indices for density (D40) and proximity responses (SD) with ± 1 standard deviation, TR_{90} with categorical recovery speed and disturbance response for fourteen focal waterbird species in the intertidal area of Sabaki estuary. Also shown are migratory behaviour, foraging tactic, flyway population trend (Wetlands International 2010) and ten-year Sabaki population trend (C. Jackson unpubl. data) for each species. Response strengths were estimated for stationary disturbances as strong for those species having both negative distance and density metrics, average for those species having metrics close to the origin or axes in the model, and weak for those species having one positive and one negative.metric for density and distance. Response strengths were estimated for mobile disturbances as strong for those species taking long to recover, average for those species taking median time to recover, and weak for those species who recover quickly.

Species	Density	Distance	Response strength (stationary)	TR_{90} (mins)	Response strength (mobile)	M/R	Forage Tactic	Dispersion	Flyway Trend	Sabaki Trend
Greater Flamingo	-0.8 ± 0.4	-0.4 ± 0.4*	Strong	> 15	Strong	M	F	A	Increasing	Stable
Lesser Flamingo	-0.8 ± 0.2*	-0.3 ± 0.2*	Strong	> 15	Strong	R	F	A	Decreasing	Decreasing
Terek Sandpiper	-0.9 ± 0.1*	-0.2 ± 0.2	Strong	> 15	Strong	M	V	Loosely A	Stable	Stable
White-fronted Plover	-0.4 ± 0.8	-0.2 ± 0.3	Strong	2 – 4	Weak	R	V	D	?	Decreasing
Curlew Sandpiper	0.0 ± 0.2	-0.1 ± 0.1*	Average	> 15	Strong	M	T	D	Stable	Stable
Marsh Sandpiper	-0.7 ± 0.3*	0.0 ± 0.3	Ambiguous	4 – 6	Average	M	V, T	Loosely A	Decreasing	Stable
Common Sandpiper	-0.8 ± 0.2*	0.0 ± 0.2	Average	6 – 8	Average	M	V	Loosely A	Decreasing	Stable
Common Greenshank	-0.2 ± 0.5*	-0.1 ± 0.1	Average	0 – 2	Weak	M	T	Loosely A	Stable	Stable
Lesser Sand Plover	0.1 ± 0.9	0.0 ± 0.2	Average	0 – 2	Weak	M	V	D	?	Stable
Grey Plover	-0.8 ± 0.3*	0.0 ± 0.0	Average	4 – 6	Average	M	V	D	Decreasing	Decreasing
Greater Sand Plover	0.9 ± 1.0*	0.1 ± 0.3	Weak	> 15	Strong	M	V	D	?	Stable
Little Stint	0.9 ± 1.0*	0.0 ± 0.3	Weak	6 – 8	Average	M	T	A	Stable	Decreasing
Broad-billed Sandpiper	0.2 ± 0.9	0.2 ± 0.2	Weak	4 – 6	Average	M	V	A	Decreasing	Stable
Common Ringed Plover	0.4 ± 0.8	0.4 ± 0.0*	Weak	2 – 4	Weak	M	V	D	Decreasing	Decreasing

M/R: M = migrant, R = resident
Foraging mode: F = filter-feeding, T = tactile, V = visual
Dispersion: A = aggregated, D = dispersed / territorial
*Metrics for which 95% confidence intervals for density and distance metrics lay inside negative or positive ranges

DISCUSSION

Patterns of disturbance

At the Sabaki estuary, disturbances by humans and livestock occur continuously during the low-tide period, but are spatially non-random. Different types of disturbance are motivated by different factors. Each user type seeks different resources and their position in the estuary reflects the availability of these resources: for example, cattle enter the estuary (usually in herds) to drink river water at specific points, where collectively they have the potential to cause considerable disturbance (Appendix F). By contrast, in areas where fishers place their gill-nets, intensity of disturbance is likely to be less (Appendix F). Although disturbance levels do vary in type and frequency between different areas within the estuary, no causal relationship was evident between disturbance intensity and bird density in the form of an inverse relationship between the two. However, the apparent absence (or comparatively lower) densities of birds in blocks frequented by cattle (Figure 2.5, Appendix F) suggests that cattle represent the most significant source of disturbance to birds. Cattle may degrade habitat quality on a local scale by causing frequent physical disturbances of birds and degrading substratum quality through trampling. Despite this, there is no overwhelming evidence that disturbance levels alone are the overriding factor determining the dispersion of birds. Nonetheless, disturbances are widespread and do occur on a near-continuous basis and birds respond to these disturbances.

Waterbird dispersion

This study represents the first examination of behavioural responses of waterbirds to disturbance in a tropical African estuary. The Sabaki estuary has a diverse bird community (Nasirwa et al 1995, Seys et al. 1995), including 86 waterbird species (Valle and Jackson 2005) of which 71 were recorded in this study. The dispersion of waterbirds on the estuary reflect substratum heterogeneity, with some species (e.g. Little Stints) being clumped within particular substrata and thus occurring at low average densities across the estuary. Overall however, foraging densities were high with an average of 115 birds/ha, exceeding most estimates of foraging densities on intertidal areas elsewhere (Hockey et al. 1992), and supporting the observation for Palearctic-breeding waders that tropical estuaries support higher densities than estuaries at boreal latitudes (Hockey et al. 1992), making them disproportionally susceptible to the effects of habitat loss and degradation (Hockey and Barnes 1997).

While patterns of local dispersion vary among species (Kalejta & Hockey 1994), waders generally occur at highest concentrations in areas where prey density and availability are high and energy expended in capturing prey is low (Goss-Custard 1970, 1985, Goss-Custard and Charman 1976). In the absence of disturbance, large numbers of waders are attracted to the Sabaki estuary which hosts a high abundance of nereid polychaetes (Houte-Hayes 2005), favoured prey of many waders (Kalejta 1993). In South Africa, the dispersion of Curlew Sandpipers has been explained by the availability of these nereid polychaetes (Kalejta and Hockey 1994). Furthermore, habitat heterogeneity influences the dispersion of birds due to interspecific differences in habitat preference.

These factors likely provide a partial explanation for the non-random dispersion of foraging birds at the Sabaki estuary (Figure 3.5). In contrast to the dispersion patterns of foraging birds, the random dispersion of roosts in the absence of disturbance presumably reflects a lack of need for any resources other than space.

Adaptive responses to disturbance

Species-specific responses to human disturbance vary due to differences in perceived risk (Lafferty 2001, Frid and Dill 2002). Similarly, the amount of foraging time lost or the time taken to recover from disturbances will vary depending on how different species trade off the risks posed by disturbance against the need to acquire energy (Gill et al. 1996, Gill et al. 2001). Furthermore, the decision to leave a foraging area will be influenced by the amount that an individual has invested in a location (e.g. establishing a territory - Gill 2007). Therefore, interspecific differences in responses to disturbance in turn are likely to be influenced by the extent of territoriality. Highest incidences of non-breeding territoriality have been reported for the Chardriidae (29% of species) and Scolopacidae (27%) (Colwell 1993), the families containing the focal species of this study (with the exception of flamingos). One noteworthy correlate of territoriality is that it is prevalent in species that use visual cues to detect prey (Goss-Custard 1985). Because visual feeders detect prey over large distances, they are more likely to interfere with foraging conspecifics than are tactile feeders and, as a result, are less likely to abandon areas in response to disturbance (Goss-Custard 1985). The two visual foragers that exhibited the weakest response to disturbance (Common Ringed Plover and Greater Sand Plover) are likely exhibiting territorial feeding behaviour at Sabaki. Conversely, some species may defend very large territories and are thus able to return to their territories without necessarily returning to that part of the territory impacted by disturbance: they may, in fact, be able to remain in their territories while simultaneously avoiding a disturbance. This scenario could explain the long recovery times exhibited by Greater Sand Plovers, a species which defends very large territories at nearby Mida Creek (Hockey et al. 1999).

Previous encounters with humans (in breeding or natal areas) will affect the response of birds to human disturbance through a process of habituation. Habituation is defined as "the relatively persistent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement" (Hinde 1970). Sustained exposure to disturbance may thus cause estuarine birds to habituate (Nisbet 2000), reducing their overall response to disturbance. The more birds are habituated to human intrusions, the less likely they are to be adversely affected by subsequent intrusions (Robert and Ralph 1975, Nisbet 2000). The persistence of potential disturbance in Sabaki means that some species are likely habituated to humans. This may explain otherwise anomalous responses to disturbance. For example, Broad-billed Sandpipers exhibited a weaker response to disturbance than other tactile-feeding, loosely aggregated foragers. Little is known about the foraging ecology of Broad-billed Sandpipers, but they may exhibit territoriality while wintering at Sabaki River Mouth making them less likely to switch foraging sites in response to disturbance or, alternatively, have habituated to human presence on the estuary.

Waders are efficient foragers but lead energetically expensive lifestyles (Owen 1993). Although lost foraging time may affect survival, these species have demonstrated adaptive responses to sustained disturbance. In response to reduced foraging time (whether caused by tidal or other factors), waders may increase feeding rates (Swennen et al. 1989) or feed at night (Dugan 1981, Turpie and Hockey 1993). Both of these options are potentially available to waders at the Sabaki, the most important of which may be nocturnal foraging. Although disturbance is less, fishing activity continues on the intertidal area throughout the night and may potentially compromise the ability of waders to contend with diurnal disturbance impacts by increasing food intake. Measurement of how these behavioural responses to disturbance differ across species provides some insight into their susceptibility to disturbance events and hence to disturbance regimes.

Intensity of responses by birds

Densities of birds in controlled disturbance plots were significantly lower than measured densities (in the absence of disturbance). The observed decrease in abundance within experimental stationary disturbance plots likely reflects the birds' perception of an elevated predation risk in the presence of humans (Frid and Dill 2002). However, species-specific responses to human disturbance vary due to differences in anti-predator behaviour and perceived level of this risk (Lafferty 2001, Frid and Dill 2002). Similarly, the amount of foraging time lost or taken to recover from disturbances will vary as species differentially weigh the risks posed by disturbance against the need to acquire energy (Gill et al. 1996, Gill et al. 2001, Frid and Dill 2002, Gill 2007). Furthermore, the decision to leave an area will depend upon the amount that individual has invested in a location (e.g. establishing a territory - Gill et al. 2001, Gill 2007). A study by Burger et al. (2007) showed that gulls return to locations within five minutes following a disturbance event, whereas waders did not recover abundances to pre-disturbance levels in the same period.

Strongest avoidance responses were exhibited by Greater and Lesser Flamingos. Flamingos are a typically flighty species (Nager et al. 1996) and these responses are therefore not surprising. Flamingos at Sabaki are subjected to chasing by locals who are paid to put birds into flight for tourists to take photographs (pers. obs., M. Kadenge pers. comm.). Furthermore, flamingos had long recovery times, and may be anticipating risk based on avoiding locations where disturbances have occurred. Although flamingos never returned to experimental plots within 15 minutes of the disturbance, both species were frequently observed walking slowly towards pre-disturbance locations after fleeing from a human disturbance. This suggests that flamingos may be partially limited by habitat availability in the estuary and disturbance is likely to incur energetic costs. Flamingo-chasing likely causes flamingos to perceive humans as predators and increases their perception of the risk posed by humans.

The fairly strong avoidance responses and slow recovery times of White-fronted Plovers and Terek Sandpipers (Figure 2.6) are likely evidence of a genuine sensitivity to disturbance. Terek Sandpipers are generally non-territorial when not breeding (Colwell 1993) and, at the Sabaki estuary, individuals foraged visually, covering large areas in pursuit of surface-active crabs. Although White-fronted Plovers are visual foragers (Hockey and Douie 1995), and therefore have the potential to interfere with the foraging of conspecifics, their response to disturbance suggests otherwise. Numbers of White-fronted Plovers at the Sabaki estuary have been decreasing over the past ten years (Table 2.2), and densities may be so low that there is no need for territoriality and therefore no pressure from conspecifics to return rapidly to the site of a disturbance. Although Grey Plovers defend territories of highly variable size within single estuaries and exhibit variable levels of territorial behaviour (Turpie 1995), if this is the case at the Sabaki estuary, then individual variability in response may explain their somewhat ambiguous placement in the model (close to one axis and far from another). It is the prevalence or otherwise of such ambiguous responses that is the key to the usefulness of the analytical approach followed in this study.

Although avoidance responses to different types of disturbance were similar, variance in the magnitude of response for each species was significant. The behaviour of waders on intertidal flats will lead to variation in responses based on factors other than (but occurring simultaneously with) the experimental disturbances which were the focus of this study. For example, waders are frequently disturbed on tidal flats by avian predators: during this study, Peregrine Falcons *Falco peregrinus* were observed to prey on small waders. Because disturbances at the Sabaki estuary were continuous, there was also the potential for birds' responses to experimental disturbance to be influenced by other disturbances occurring at the same time. Such confounding events could have influenced e.g. recovery times. These confounding factors aside, the confidence of vulnerability estimates is greatest for species positioned furthest from the origin and axes in the model

Model utility

Most studies of disturbance examine its effects on species grouped at the family level or higher or focus on single-species issues. Models which predict reductions in carrying capacity due to disturbance may be useful for prioritizing sites for the management of disturbance, but isolating and quantifying the relevant ecological variables required to construct such models is often impossible (Cayford 1993). Furthermore, such complex analyses, including those used to examine the landscape-level effects of disturbance on waterbirds, may be unrealistic when funds and time are limited (Burton 2007). Therefore, rapid techniques for assessing vulnerability can be a useful aid for conservation planners in the absence of more comprehensive data (Hockey and Curtis 2009).

The analytical approach adopted here, in the form of a simple, unitless model, has not previously been attempted for site-specific, multi-species responses to disturbance, although analogous visual approaches have been used to assess the relative extinction vulnerabilities of plants, birds and lemurs, based on their life-histories and ecological traits (Bond 1995, Hockey and Curtis 2009). The high densities of waders at the Sabaki and elsewhere in the tropics (Hockey et al. 1992, Hockey & Barnes 1997) makes it possible to quantify behavioural responses by multiple species in fixed observation periods and sites (i.e. holding as many other factors as possible constant). This in turn allows the mapping of species in a 'vulnerability space' (Figure 2.3), providing a visual tool, based on multiple response criteria, for the rapid assessment of interspecific differences in vulnerability to disturbance. If species fell along a simple, linear gradient of increasing response to disturbance, and if the three metrics used in this study (based on approach distance, density and recovery time) were truly interchangeable, then the model output is expected to resemble that in Figure 2.6, with no points lying in the upper left or lower right quadrants. In the Sabaki model, only one of 14 species fell (marginally) into this 'equivocal space' (Marsh Sandpiper). An additional three species (Common Sandpiper, Grey Plover and Little Stint – Figure 2.6) fell outside the predictions of the 'perfect model' (Figure 2.3), and Greater Sandplover had an unexpectedly long recovery time (Figure 2.6). The remaining nine species (64%), however, fell very close in vulnerability space to predictions based on the assumption that all three metrics are fully interchangeable. Given the rapidity with which it was possible to collect the data, this is an encouraging result.

Conservation implications

As yet, no formal protection or management plan exists for the Sabaki River Mouth IBA and little is known about the effects of sustained exploitative use of the estuary resources on waterbirds. The waterbird community at the Sabaki is notable among Kenya's coastal wetlands in terms of both numbers and diversity of birds (Seys et al. 2005). Silty habitats favoured by many wader species are threatened by climate-change-associated sea-level rise and wader densities are expected to decrease in muddy estuaries (Austin and Rehfisch 2003). Significant land-use changes have occurred at the Sabaki from increased sedimentation and areas of sandy habitat have increased (Brakel 1984). It is not known whether the area of intertidal habitat has decreased, but degradation is expected from disturbance to macrofaunal communities with an increased frequency of deposition events (Houte-Hayes 2005). Habitat change may compound the possible impacts of disturbance, and in the absence of evidence to the contrary, managing disturbance levels in the estuary will likely mitigate threats of habitat degradation and loss.

The conservation implications of disturbance are not clear, given the difficulty in attributing behavioural response to disturbance at the population level (Hill et al. 1997, Gill et al. 2001). However, by combining information from multiple sources, the model allowed identification of species for which disturbance is a conservation concern. Assuming that disturbance levels have increased in the past decade at Sabaki estuary, (see Chapter 3), those species exhibiting declines may reflect degradation of the habitat at Sabaki from disturbance. Greater Flamingos are likely impacted by disturbance given their strong avoidance responses and declining population trend at Sabaki despite a stable population trend in the flyway. The impacts are less clear for Lesser Flamingos, whose declining population trend at Sabaki may be an auto-correlation with their flyway population trend. However, Lesser Flamingos are of conservation concern (Near Threatened: IUCN 2010) and both flamingo species are of potential economic value to tourism at the estuary (see Chapter 3). Therefore, disturbance of this species should be managed to mitigate future declines. Similarly to Lesser Flamingos, the decline in Grey Plovers and Common Ringed Plovers may be an autocorrelation with flyway-level population declines. It would appear, however, that the weak response observed in Common Ringed Plovers suggests that this species is highly territorial and accordingly less likely to give up habitats in response to disturbance. Similarly, the weak response exhibited by Broad-billed

Sandpipers, when combined with their stable population in Sabaki despite flyway-level declines, suggests that disturbance does not significantly impact the dispersion of this species. Conversely, White-fronted Plovers, being resident species, exhibit local long-term declines and are unexpectedly sensitive to disturbance. In summary, disturbance is likely impacting the distribution of some species at Sabaki estuary, however most noticeable and convincing impacts from available information are for Greater Flamingos, Lesser Flamingos, Terek Sandpipers, and White-fronted Plovers. For those species exhibiting flyway-level declines and ambiguous responses to disturbance, disturbance should still be considered a possible threat to these species at Sabaki and efforts should be made to minimize bird disturbance where possible, in order to mitigate flyway-level population declines.

CHAPTER 3. Costs and benefits of conserving an Important Bird Area

INTRODUCTION

One of the greatest challenges facing conservation planners is justifying increases in biodiversity protection at the expense of short-term economic development. This issue is particularly challenging in developing countries which both contain much of the world's biodiversity and also face the pressing need to reduce poverty and contend with overpopulation (Wells 1992). Attempts to remedy the mismatch between conservation and development objectives are evident in the growing field of poverty-based environmental management. New solutions are being proposed to achieve "double sustainability" of human livelihoods and biodiversity conservation (Cernea and Schmidt-Soltaur 2003). However, conflict still exists when the protection of biological resources requires the exclusion or regulation of access of people to biodiversity resources. This is especially true for the rural poor living adjacent to sites of conservation priority whose livelihoods may be impacted by exclusion. Funding for conservation is limited in the tropics and economic opportunities for impoverished peoples are often compromised at the expense of conservation action (Wells 1992). One way of harmonizing the sustainable management of natural resources with the goals for economic sustainability is through the development of local ecotourism activities. These activities have the potential to offset the costs of conservation and have gained in popularity in many developing countries.

Although resources for biodiversity conservation are limited, cost benefit analyses have not traditionally been integrated into conservation planning (Naidoo and Ricketts 2006). However, integrating the costs of conservation into conservation assessment is increasingly topical (Balmford and Cowling 2006). Comparing the costs and benefits of conservation activities can guide decisions on where conservation versus development should occur (Naidoo and Ricketts 2006, Naidoo et al. 2006). In Africa, analysis of the costs and benefits of creating conservation reserves has shown that the contingent value of reserves to tourists may outweigh the costs of conservation at specific locations (Naidoo and Adamowicz 2005). Thus, if appropriate institutions for redistribution can be implemented, ecotourism may provide a viable substitute for livelihoods dependent on destructive activities such as overfishing or charcoal burning.

Integration of development and conservation goals is a key step towards reducing poverty levels in areas of conservation importance (Adams et al. 2004) because rural people are most dependent upon the resources provided by the surrounding environment for survival. In sub-Saharan Africa, wetlands provide important goods and services to local people but are threatened by overuse (Schuyt 2005). Poor planning has resulted in the marginalization of the rural poor and inadequate access to wetland resources in much of Africa (Schuyt 2005). However, human use of wetlands is not well-documented (Ratner et al. 2004). To implement successful programs in rural communities, clear conceptual frameworks are required (Adams et al. 2004). The basis for a successful framework is informed decision-making. A full understanding of patterns of resource use and the value of natural resource assets allows conservation planners to take an integrated approach at managing biodiversity in a participatory manner (Taylor et al. 2001).

Therefore information is needed in order to ensure that conservation does not occur at the expense of local livelihoods. Social responsibility aside, community-based natural resource management depends upon the support and custodianship of local people (Shackleton et al. 1998), which can only be gained when local people actively participate in and enjoy the benefits of conservation activities.

Community-based ecotourism schemes are of emerging importance in Kenya's Important Bird Areas, where the Arabuko-Sokoke Schools and Ecotourism Scheme serves the dual purpose of generating funds for conservation and the secondary education of locals. Other near-by successful community-based initiatives include the Kipepeo Butterfly project (at Gede National Park) and Mida Creek community reserve (Appendix A). Kenya's National Environment Action Plan stipulates the need for communities to gain tenure of lands and develop modes of sustainably managing wetland resources (Kenya NEAP 1994). In Kenya, 46% of the total population and 49% of the rural population, respectively, live below the poverty-line (CIA 2010). Most of the rural poor depend upon agriculture, pastoralism, and fisheries to sustain their livelihoods (Kinyua 2004). For this reason, the rural poor are prone to natural shocks and stresses associated with drought and collapse in fisheries. Improving and diversifying sources of income (e.g. fisheries, ecotourism) will reduce the exposure of rural poor to stress and shocks (Ellis 1999). Investigating the potential for income-generating conservation activities as a substitute for destructive extractive activities reveals the opportunities and challenges facing conservation in communities adjacent to sites of conservation priority. Developing ecotourism in Important Bird Areas (IBAs) such as Arabuko-Sokoke and Mida Creek provide the opportunity for communities to protect biodiversity resources at sites of conservation priority and simultaneously facilitate livelihood diversification.

Located within 30 km of Arabuko-Sokoke Forest Reserve and Mida Creek, Sabaki estuary is a popular destination for tourists on the central coast of Kenya and also used as communal land by more than 2000 people. Although tourism has occurred at the estuary for decades, the community realizes no substantial benefits from tourism. Furthermore, extractive activities are unregulated and may pose a risk to the sustainability of wetland resources. As an Important Bird Area (IBA), Sabaki River Mouth is a site of conservation priority for its congregations of waterbirds and efforts to develop sustainable ecotourism at this location are in the early stages. To develop successful ecotourism ventures, ascertaining the preferences of tourists is a preliminary step to maximize the value of the area for tourism and biodiversity. A socioeconomic assessment of the local community revealed that more than 90% of households expressed the desire to see the estuary formally protected in some manner (Koskela and Ruuska 2009). The Sabaki River Mouth IBA could be an ideal site to develop and formalize a community-conservancy funded by ecotourism, however the information necessary to implement a strategy has not been gathered.

This study quantifies the composition of household income for a community living within the boundaries of Sabaki River Mouth Important Bird Area (IBA), one of Kenya's 60 IBAs. Patterns of resource use and the potential value of developing ecotourism are explored. A combined qualitative-quantitative cost-benefit analysis is performed to evaluate whether developing ecotourism at Sabaki can off-set the cost to livelihoods of regulating extractive activities.

METHODS

Value to local livelihoods

Surveys were conducted for households in Sabaki Village, the community adjacent to Sabaki estuary. Heads of household (the person in charge of making household decisions) were interviewed regarding the composition of household incomes and natural resource use (N = 190). Questionnaires (Appendix H) were administered by two trained enumerators in English, kiSwahili, and kiGiriama (the local vernacular) between 15 October and 24 November 2010. Respondents were instructed to answer questions on behalf of the entire household comprising all persons regularly eating from the same pot (Vaughn 1985, Appendix H).

At the beginning of household interviews, respondents were given 100 beans and instructed to divide these beans amongst a series of income-source categories. Categories for income-sources were based on known income-sources described previously in a study conducted in Sabaki Village by Koskela and Ruuska (2009). Household income sources included: livestock, crop products, handicrafts, harvested raw materials, charcoal, fuelwood, fish and prawns, crabs and vongoles (a local gastropod), water, employment, business, remittances (money mailed from family or friends) and government welfare. Respondents placed a pile of beans representing the proportion of total income on a laminated placard corresponding to the category or activity from which income is derived. After dividing the beans among applicable categories, respondents were asked to further divide beans to indicate the proportion of income for each category derived from resources within the Sabaki River Mouth IBA (defined as the estuary itself and surrounding scrubland to 2 km from the river banks), and then from this amount, the proportion of income derived from the sale of these materials. For business and employment, respondents were rather asked to divide beans according to the proportion of this income that is derived from the tourism sector. Respondents were asked about their attitudes towards increased tourism in the IBA and regulation of resource extraction activities. Respondents were also interviewed regarding their fishing and water abstraction activities. To examine the substitutability of estuary resources, interviewers asked respondents about the availability of alternative sites for specific extractive activities. Estuarine resources utilised by locals were fish, food and water for livestock, medicinal plants, and drinking water. Cultural and leisure uses were also assessed to ascertain the sociological importance of the estuary to local people.

The proportion of households engaged in the use of each natural resource or income-generating activity was calculated to estimate the value of these activities to the community and examine the extent of livelihood diversification at Sabaki. Summary statistics provided quantification of household income, the proportion of income derived from natural resources in the immediate Sabaki River Mouth IBA and the proportion of production sold for monetary income. It was important to understand the economic role of cattle for two reasons, 1) cattle represent a significant source of disturbance in the estuary (see Chapter 2) and, like many rural communities in Africa, 2) cattle may represent a banking system employed by locals to protect their livelihoods in times of economic hardship (Schuyt 2005). To separate the economic importance of cattle from the livestock category, the proportion of households owning cattle was calculated, as was the proportional value of cattle to the income of those households.

To identify patterns in resource use, important sites for water abstraction were mapped by ground-truthing, and densities of humans and livestock in the intertidal and directly adjacent areas were mapped by conducting instantaneous scans of activity in the intertidal area (see Chapter 2). Maps were synthesized using ArcView GIS 3.3 and all statistical analysis and graphs were produced with Microsoft Excel 2007 (Microsoft 2007).

Current and potential tourism value

The number of tourists visiting the Sabaki estuary was estimated by counting all visitors as they arrived over a 30-day period from 5 October through 4 November 2010. Visitors were classified as domestic if they were residents of Kenya, foreign if they were residents of countries outside Kenya, and students if they came with a school group. In Kenya, the high and low seasons for foreign tourists are somewhat unpredictable and fluctuate on a week-to-week basis (E. Utumbi pers. comm.). However, our estimates over a 30-day period were made during a low “on” season and likely represent close to an average annual rate of visitation for foreign tourists. Students and domestic tourists visit steadily through the year (barring school holidays) and thus our counts likely captured sufficient variation to estimate annual visitation rates. One-hundred and forty-eight tourists were interviewed on-site using the questionnaire in Appendix I. Respondents were asked to give their reasons for visiting the area, to identify important features of the estuary comprising the value of their experience and the amount they would be willing to pay for an entry fee to visit the estuary. Tourists were interviewed by trained enumerators in English, Italian, and kiSwahili, reflecting the dominant vernaculars of tourists to the area. To ascertain which estuary features and resources added or detracted from the value of the area as a tourist destination, respondents were asked whether cattle, fishers, or beach boys enhanced or detracted from their experience. The economic potential of tourism at the estuary was evaluated using the contingent valuation method, whereby visitors were asked if they were willing to pay an entry fee to visit the area, and subsequently, how much they would be willing to pay. The first scenario applied for the contingent valuation method was the estuary in its current state and the second was a hypothetical scenario in which improvements had been made to infrastructure in the Sabaki River Mouth IBA. Visitors were asked how possible improvements to tourist infrastructure would influence the value of their experience at the estuary (Appendix I).

Contingent valuation of tourism at Sabaki estuary was achieved by calculating a mean willingness-to-pay value of both domestic and foreign tourists for both the current and hypothetical (improved infrastructure) scenarios. Aggregate willingness to pay was calculated for both the current and hypothetical scenarios by extrapolating visitor count data from a 30-day sample across 12 months.

RESULTS

Livelihood composition

Households in the study area were large but variable in size, having a mean of 9.0 ± 4.5 S.D. people eating from the same pot. Households engaged in a wide variety of productive activities (Table 3.1). Every household collected at least some of their own water and more than 90% of households engaged in fuelwood collection, harvesting of raw materials and crop production (Table 3.1). More than half of all households derived income from one or all of: water and fuelwood collection, crop production, raw material collection, livestock production, fisheries, employment, small business, remittances, handicrafts, and charcoal burning (Table 3.1). Only one of the households interviewed claimed to receive any form of government social welfare.

On average, household income is derived from natural resources (56%), farming (26%), employment or business (17%, Table 3.1). Only 4% of the mean proportional contribution to household livelihoods is derived from remittances, government pension, or social welfare. A mean of

6.3% ± 0.3% SD of total household income was generated by tourism-related business or employment, however, this varied widely between households (Table 3.1). Crab and vongole collection and social welfare are the two categories which generate income for the fewest households and also contribute the lowest mean proportion of household income (less than 3%). Indeed the mean proportional composition of household income is similar to the proportion of households deriving income from each source for water, crops, and fuelwood (Table 3.1).

Most of the income that households derive from charcoal production, crab and vongole collection and livestock production is realised as cash income from sales of these products (Table 3.1). Conversely, fishing, handicraft production, raw material and fuelwood collection, water collection and crop production are mainly carried out for subsistence use (Table 3.1), although sales of some of these, such as fish, are still significant. Sales constitute 16.7% of the total household income and the most important sources of cash income are from (in descending order from largest mean proportion) employment, business, livestock sales, remittances, charcoal sales and fish sales (Table 3.1).

Table 3.1. Results of household surveys showing the proportion of households participating in, or mean income derived from, each of 14 categories or activities. Resources and activities are categorized as natural resources, pastoral or farm activities, or formal sources of income, and placed in ranked order.

	% hh	% hh, IBA	% sell	% income	% income IBA	% sold	% cash
Natural Resources							
Water	100.0	98.9	8.9	14.7 ± 0.4	97.5 ± 0.8	4.3 ± 1.1	1.7 ± 0.3
Fuelwood	97.9	97.4	11.1	12.2 ± 0.4	98.7 ± 0.6	6.3 ± 1.9	2 .0 ± 0.5
Fish	75.8	75.8	34.7	7.8 ± 0.5	95.5 ± 1.2	28.5 ± 3.0	6.0 ± 1.0
Raw Materials	91.1	90.0	12.1	7.7 ± 0.3	98.7 ± 0.8	8.3 ± 1.7	1.7 ± 0.4
Charcoal	57.4	56.8	40.5	5.7 ± 0.5	99.1 ± 0.9	69.9 ± 4.3	10.6 ± 1.3
Handicrafts	58.9	56.3	24.7	5.5 ± 0.4	92.2 ± 2.3	27.2 ± 3.3	4.0 ± 0.9
Crabs	33.7	33.2	20.0	2.5 ± 0.3	97.0 ± 1.9	59.0 ± 6.2	3.9 ± 1.3
Pastoral and Farm							
Crops	97.4	93.2	1.6	14.1 ± 0.5	84.2 ± 3.0	2.4 ± 1.4	0.9 ± 0.5
Livestock	88.9	86.8	8.9	9.4 ± 0.4	90.9 ± 1.8	54.6 ± 8.4	13.8 ± 2.2
Cattle	28.9	-	-	2.0 ± 0.3	-	-	-
Formal			**% tourism**			**% tourism**	
Employment	74.2	51.6	22.1	9.2 ± 0.6	54.2 ± 3.7	51.5 ± 8.7	24.5 ± 39.3
Business	73.7	56.8	14.2	7.6 ± 0.5	67.9 ± 3.5	20.9 ± 4.0	20.3 ± 32.7
Remittance	60.0	-	-	4.0 ± 0.3	-	-	10.7 ± 19.6
Government Welfare	0.5	-	-	0.0 ± 0.0	-	-	0.0 ± 0.0

% hh: The proportion of total households units participating in each income-generating category.
% hh, IBA: The proportion of households utilizing the Sabaki River Mouth IBA for each category.
% sell: The proportion of households selling at least some of their production from each category.
% income: The mean proportional contribution (± 1 S.D.) of each category to household income.
% income IBA: The mean proportion (± 1 S.D.) of each category derived from or conducted within the boundaries of the IBA.
% tourism: The mean proportion (± 1 S.D.) of income derived from the tourism sector.
% sold: The mean proportional contribution (± 1 S.D.) of each category to cash income.

Attitudes towards development

Most respondents (92%) felt they would benefit from increased tourism activities at Sabaki River Mouth IBA. In addition, most households (93%) were in favour of increased regulation of resource extraction activities in IBA. The remainder of respondents were divided amongst those who responded partially (4%, 6%), uncertainly (4%, 3%), or negatively (4%, 6%) towards increased tourism and regulation of resource extraction activities, respectively.

Resource use in the IBA

More than 80% of all land-based activities were conducted within the boundaries of Sabaki River Mouth IBA (Figure 3.1). Although still highly localized to the IBA, crop and livestock production were less localized than resource extraction activities. Fuelwood, raw materials, and charcoal are collected and processed in the *Acacia* scrubland adjacent to the estuary (Figure 3.1). Livestock watering in the intertidal area is concentrated in areas closer to human settlements where reeds and mangroves do not obstruct access to the intertidal flats (Appendix F) and grazing occurs on both the north and south sides of the river (Figure 3.1).

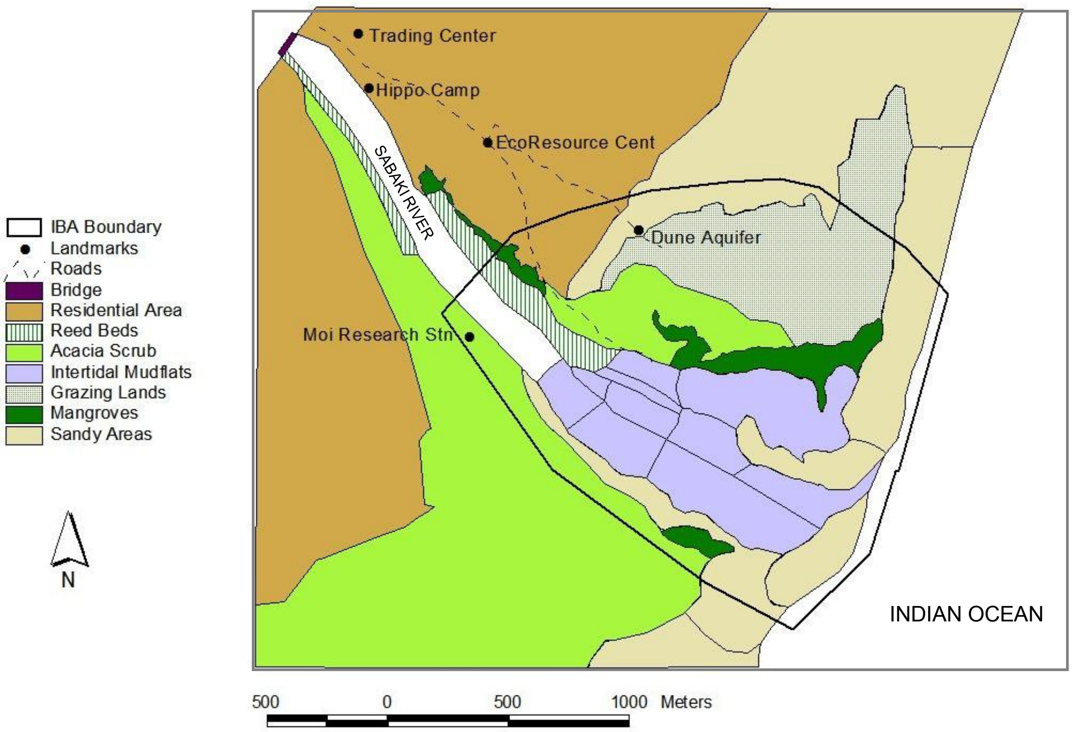

Figure 3.1. Map of Sabaki estuary showing the estimated IBA boundary, major landmarks, water sources and habitat type or land use. Mapped locations were ground-truthed in October 2010. The trading-center is the commercial area of Sabaki Village where household concentrations are highest. Hippo Camp is a restaurant and guesthouse frequented by visitors, the Eco-Resource Center is a visitor's center very recently constructed by the IBA site-support group, and Moi Research Station is a derelict building on land tenured by Moi University.

All households collect some of their water from natural (non-piped) sources .Household water is collected from a variety of locations. Very few households collect water from seasonal freshwater pools. Because the questionnaire was administered during the dry season, responses could have been biased against use of these sources (which are present only in the wet season). The water resource utilized by most households is an aquifer in the sand dunes on the north side of the estuary (Figure 3.1, 3.2), where local women dig shallow wells to abstract the water and manually transport it to their dwellings. Most households also utilized river water directly, and bore-holes were utilized by about one quarter of households (Figure 3.2).

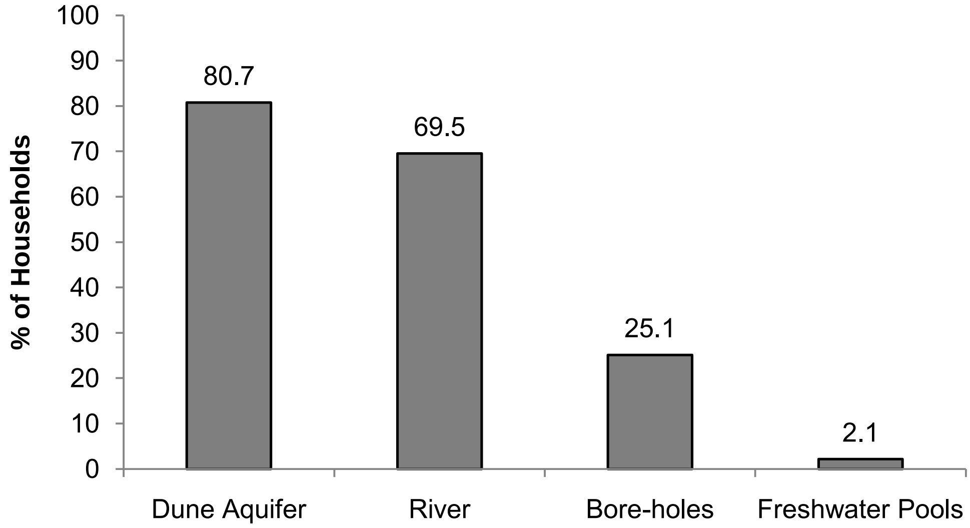

Figure 3.2. Percent of households in Sabaki Village utilizing various water sources. The location of the dune aquifer is shown on Figure 3.1, river water pertains to water collected directly from Sabaki estuary and Sabaki River, bore-holes are mainly located on private land, and freshwater pools are located on the perimeter of residential areas, scrubland, and dunes during the wet season.

Of households that engage in fishing in the estuary, 67.9% fish at the mouth of the estuary, 65.7% fish in the middle estuary region, and 73.7% fish along the banks of the river more than 1500 m upstream from the open shore (river mouth). A few respondents indicated their use of traditional “Migono” traps for fishing, while the majority of households interviewed used fishing line (69.6%) and/or gill and seine nets (67.9%). A total of 20.7% of households indicated that they use mosquito nets for fishing, but given that this is illegal, the actual proportion is likely to be higher. Estuary scans (Chapter 2) revealed that fishers were distributed throughout the estuary but at highest concentrations in the middle regions of the intertidal area where river flow is highest (Appendix F).

Substitutability of IBA resources

Resources derived from the estuary had low substitutability, with between 88 – 92% of households claiming that availability of alternative sites for watering livestock, fishing, and water collection was low. Medicinal plant collection (mainly for mangrove fruits, M. Kadenge pers. comm.) was more substitutable than other natural resources, but most respondents still cited that alternative site availability was low. Leisure and cultural activities were more substitutable, with 45% and 37% of households indicating that there is relative medium availability of alternative sites for leisure and cultural activities (Figure 3.8).

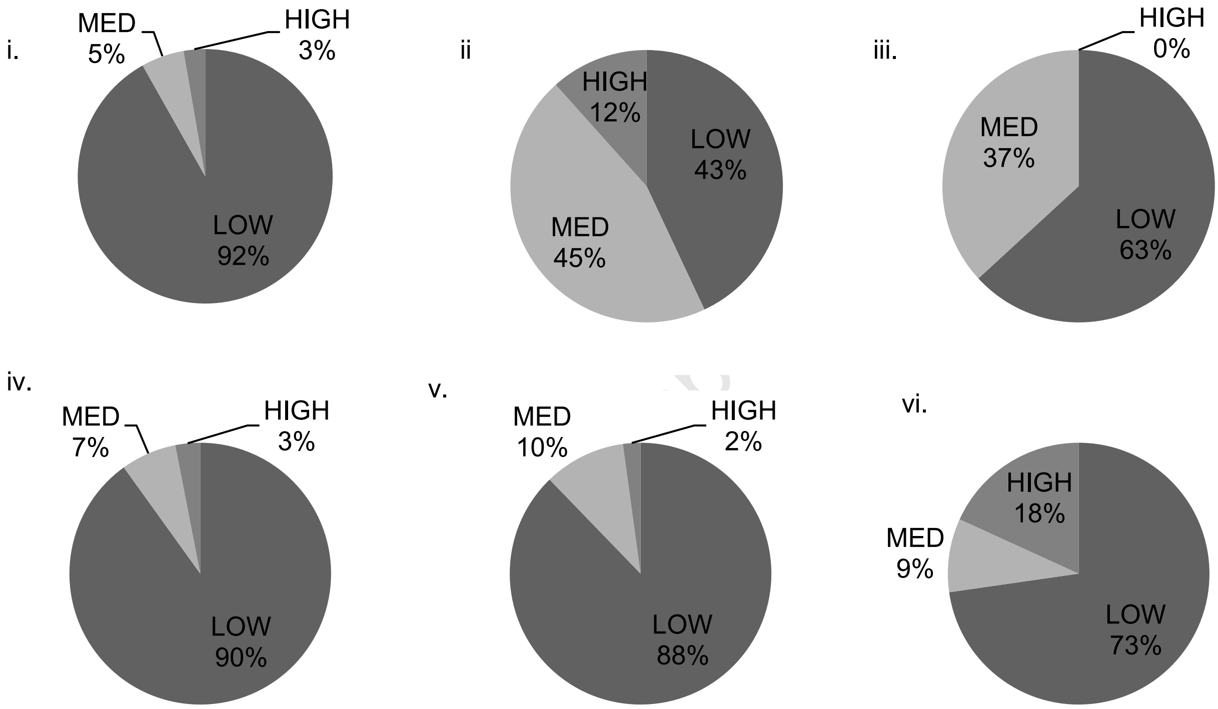

Figure 3.3. Proportion of households indicating that availability of alternative sites for i. Livestock watering, ii. Leisure, iii. Cultural uses, iv. Fishing, v. Water collection, and vi. Medicinal plant collection are low, medium, or high.

Tourist visitation rates

Over a 30-day period from 6 October to 4 November, 837 visitors were counted at the Sabaki estuary. Recreational users came to Sabaki River Mouth at a mean daily rate of 5.13±7.42 for locals, 5.51±12.11 for foreigners. On only one day during the study period were 0 visitors counted at Sabaki River Mouth IBA. Visitor numbers were dominated by students from schools within Kenya on educational field trips. The students tended to come in groups and frequency of visits was more sporadic than for tourist visitation. A total 375 students from 7 school groups (3 primary, 4 secondary) from Malindi, Voi, Nairobi, and Mombasa visited the estuary during the period of study. Remaining visitation consisted of 192 domestic tourists and 270 foreign tourists.

Current and potential tourism value

Nearly all tourists (97%) were willing to pay entry fees to visit the estuary under the current scenario (N = 148). However, willingness-to-pay values were significantly different between domestic (n = 60) and foreign (n = 68) tourists (Kruskall Wallis: p = 0.018). Resultant willingness-to-pay values were highly skewed to the left, therefore geometric mean values were calculated as a better representation of true contingent value. Geometric mean willingness-to-pay values are shown in Table 3.2. Annual economic potential of tourism, estimated from annual aggregate geometric mean willingness to pay, is 325 255.67 KSh, or approximately 2500.00 US$ per annum. This value does not account for entry fees (which may be paid by school groups) or seasonal fluctuations in tourist visitation rates and therefore represents a rough estimate of unrealized revenue from tourism at Sabaki estuary.

Under the hypothetical scenario of improved tourism infrastructure, willingness-to-pay values were not significantly different between domestic and foreign tourists (Kruskall-Wallis: p = 0.208). Although not statistically significant, mean values for willingness to pay were still lower for locals and because most entry-fee systems in Kenya are tiered, willingness to pay is presented separately for domestic and foreign tourists in Table 3.2. Resultant willingness-to-pay values for the hypothetical scenario of improved infrastructure were not skewed and are thus presented as averages. If improvements to infrastructure were made, foreigners and locals were willing to pay an average of 12.2% and 10.7% more, respectively, than they would be willing to pay under current conditions. If improvements were implemented, the annual economic potential of tourism, estimated from annual aggregate geometric mean willingness to pay would increase dramatically from current conditions to 1 535 232.73 KSh = 11 700.00 US$ per annum. This is an increase of 1 209 000 KSh = 9 200 US$ per annum from the aggregate willingness-to-pay values under current conditions.

Table 3.2. Willingness-to-pay values derived from contingent valuation of tourism at Sabaki estuary under current conditions and with improved tourism infrastructure. Values are means (±1 S.D.) of values divulged in interviews with both domestic and foreign visitors to Sabaki estuary in October and November 2010.

	Current scenario	**Infrastructure improved**
Domestic WTP	72 ± 163 KSh = 0.54 ± 2.02 US$	429 ± 413 KSh = 5.01 ± 4.82 US$
Foreign WTP	95 ± 360 KSh = 0.72 ± 4.45 US$	503 ± 402 KSh = 5.88 ± 4.70 US$
Aggregate annual WTP	326 000 KSh = 2500.00 US$	1 535 000 KSh = 11 700.00 US$

KSh = Kenyan shillings
US$ = U.S. dollar

Visitor preferences

Most visitors came to Sabaki estuary to see the Hippopotamuses *Hippopotamus amphibius*, although the scenery, flamingos, and local people also were important (Figure 3.4). For those visitors who were attracted to the estuary by its bird-life, most people came to view waterbirds, although species diversity, rarity, abundance, and bushbird viewing also were important (Figure 3.5).

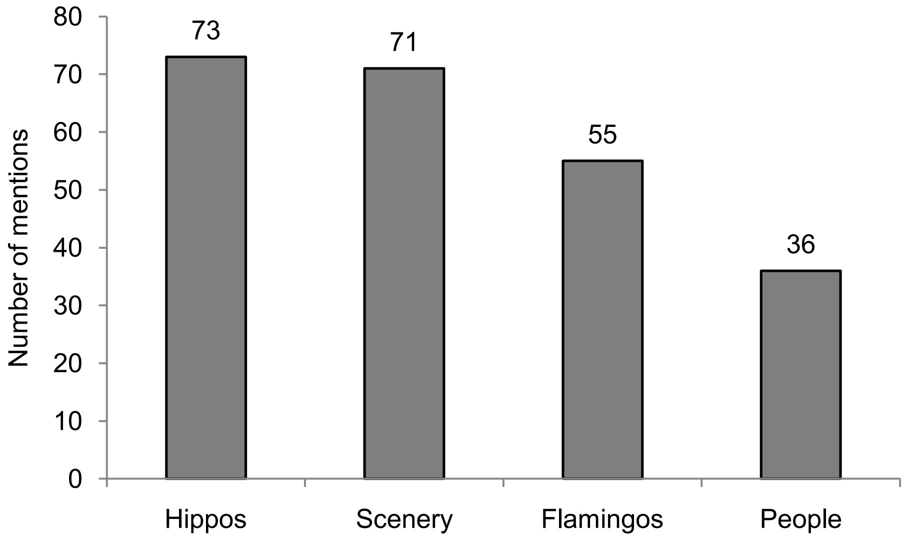

Figure 3.4. Relative importance of different features of the Sabaki estuary.

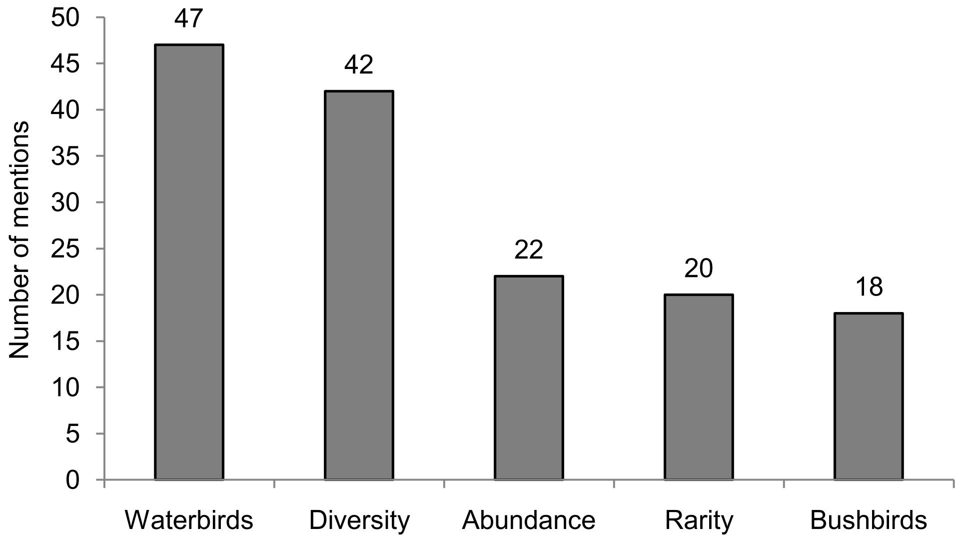

Figure 3.5. Priorities for birdwatchers at the Sabaki estuary.

Tourists were asked to score the value of potential infrastructure improvements from those that would detract from or enhance their experience (on a scale of 1 = strongly detract, 3 = neutral, 5 = strongly enhance). Overall scores were developed by averaging scores given by individuals. The most preferred infrastructure was road improvement for the road leading into the estuary and all improvements gained a mean score of more than 3 (Figure 3.6).

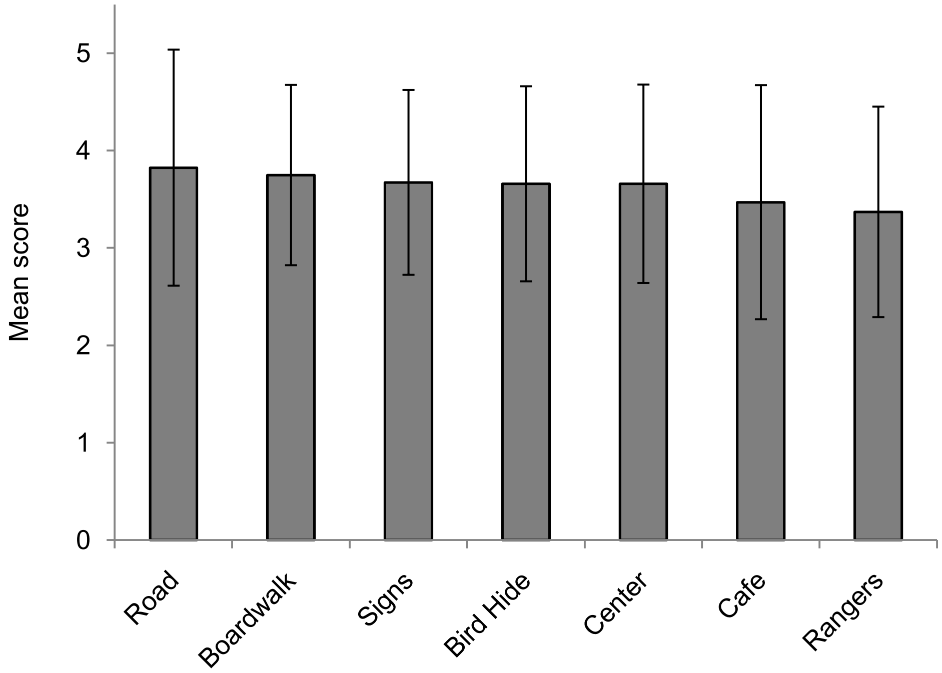

Figure 3.6. Mean scores (± 1 S.D.), from a scaled gradient of 1 = “strongly detract from” to 5 = “strongly enhance”, for improved infrastructure according to tourists interviewed in October and November 2010 at Sabaki estuary.

Table 3.3. How existing estuary users influence the value of a visiting experience to tourists at Sabaki estuary.

	Not encountered	Detract	Neutral	Enhance
Beach boys	21%	37%	20%	22%
Fishers	16%	7%	29%	48%
Cattle	17%	11%	30%	42%

The majority of visitors who had encountered fishers and cattle responded that their presence enhanced their experience at the estuary (Table 3.3). On the other hand, fewer tourists said that the presence of beach boys enhanced their experience (Table 3.3). Between 16 – 21 % of the time, visitors had not encountered these types of local activity in the estuary. Overall visitors were keen to see fishers in the estuary, fairly indifferent to the presence of cattle and yet many enjoyed seeing them, and the presence of beach boys was a detraction for many tourists (pers. obs.).

DISCUSSION

Statistics on traditional lifestyles and utilization of biodiversity resources at Sabaki estuary demonstrate the importance of the IBA to the income of local people. Natural resources comprise the majority of household income (56%) for livelihoods at this location. However, increasing population size, low education levels, and unregulated use of natural resources may lead to overexploitation or collapse of the resource base. Wise, conservation-oriented management of the resources at Sabaki can serve the dual purpose of reducing livelihood insecurity and conserving the area for its globally significant populations of birds (see Study Area and Chapter 2). Achieving this goal requires knowledge regarding the value of particular resources to household income in order to make informed decisions with sustainable outcomes.

Livelihoods and estuary use

The diversification of livelihoods at Sabaki is typical of vulnerable livelihoods in an impoverished rural setting (Ellis 2000). Matching uneven flows in resource availability with continuous requirements for household income has driven livelihood diversification in much of sub-Saharan Africa (Carter and May 1997). Diversification of livelihoods in Sabaki is likely the result of previous stresses and shocks, such as the three major famines which occurred in Sabaki during the 20^{th} century (see Study Area). Wetlands provide resources which allow the rural poor to spread risk by broadening their activity portfolios (Lannas and Turpie 2009, Schuyt 2005). Furthermore, wetlands function as a safety net against shocks and stresses and are especially important for households not dependent upon social welfare systems. The households of Sabaki do not receive social welfare and thus their dependence on the estuary as a safety net is acute. In other sub-Saharan nations, such as South Africa, 11% of rural households are dependent upon social security (Carter and May 1997), which acts as a buffer against the potential overuse of wetland ecosystems and other natural resources (Lannas and Turpie 2009).

Despite the sandy, nutrient-poor soils in the region, agriculture and livestock are among the top five contributors to household livelihoods in Sabaki Village (Figure 3.1). More than 85% of households are engaged in farming (crop and livestock production) which constitutes 23% of household income. Crop production and livestock were less localized to the estuary region than collection of natural resources, as many households have plots (shambas) in adjacent areas or keep livestock outside of Sabaki. After employment and business, livestock constitute the most important source of cash income for families. Thus, livestock-keeping at Sabaki probably represents a form of banking. Livestock banking systems usually operate as follows: the first livestock purchased is usually a chicken and money is saved from selling eggs and chicks. When sufficient money is saved, the household purchases a goat which is then subsequently exchanged for a cow. The cash income received from the sale of a cow or cattle may then be used to invest in education for their children (Schuyt 2005). For this reason, cash income from livestock keeping is likely highly important for continuing development in the village.

Average per capita food production has declined in many African countries, per capita calorie consumption has stagnated at low levels, and roughly 100 million people in sub-Saharan Africa are food insecure (Cleaver and Donovan 1995). In Kenya, agricultural productivity is influenced considerably by weather, and fluctuations in productivity, in turn, influence food security for the rural poor (Kinyua 2004). To mitigate weather-induced food nsecurity, most rural families in sub-Saharan Africa have multiple income sources and gain 30-50% of income from non-farming activities (Reardon 1997). The livelihoods of people at Sabaki are less-dependent on farming activities than these average estimates and are highly diversified among an array of activities and resources. Average households in Kenya derive 38% of their productivity from non-farm income sources (Suri et al. 2008), while 56% of the household income in Sabaki is from natural resources alone. This illustrates the above-average reliance of livelihoods in Sabaki on natural resources compared with average rural households in Kenya. However, these reliances are localized and driven by the availability of natural resources and traditional practices of rural people.

Fishing and livelihoods

Although fishers constitute the greatest proportion of people present in the intertidal area of the estuary (see Chapter 2), the contribution of fish to household income is relatively little (7.8%). More than 90% of the income derived from fishing by the people in Sabaki comes from the estuary itself and fisheries resources here are highly unsubstitutable (Figure 3.3). Proportions of households using different areas of the estuary are relatively even between the mouth of the river, the intertidal area, and the river banks. Informal interviews with local fishers revealed that the majority of fishers in the intertidal area sell most of their catch. However, for fishers who are residents of Sabaki, fishing is mainly for household consumption (Table 3.1). Fish provide an important source of protein for local people (more than 50% of livestock production is sold) and therefore protection of fishery resources is key for livelihood security.

Households employ a variety of fishing methods including gill-netting, beach-seining, and line-fishing. Previous studies have shown that community-based management of a gill-net fishery can lead to sustainable outcomes (Kyle 1999). However at Sabaki, fishing activities are unregulated and likely impact the quality of habitat for waterbirds (see Chapter 2) and local fish stocks. This is because fishing activities are extensive in the estuary (Appendix F) and illegal and unsustainable fishing practices are widespread. For example, many households at Sabaki received mosquito nets from a USAID malaria prevention initiative in 2001 (M. Kadenge, pers. comm.) and have since repurposed the nets to capture small fish and prawns. The use of mosquito nets (see Results) and undersized nets is widespread (pers. obs) and these unsustainable fishing practices may reduce fishery stocks at Sabaki and impact the livelihoods of merchant fishermen and households in Sabaki Village. Furthermore, informal interviews with fishermen and villagers revealed that waterbirds often drown in gill-nets at high tide. The majority of species caught are terns and further research should aim to understand the extent and frequency of waterbird by-catch in the fishery. Proper inventories of the fishery stocks at Sabaki have not been conducted so comparative studies cannot examine the effect of current practices on fish stock size and composition, but collapse may occur when unsustainable practices proliferate. Clearly, management should aim to address the possible impacts of the fishery on native fauna in order to sustain these key estuary resources.

Water for households and livestock

Water comprises a significant portion of household livelihoods, as local people at Sabaki source their water from both natural aquifers and the river itself during low tide. A like study conducted in western Kenya showed that rural livelihoods were similarly dependent on freshwater resources from an adjacent wetland. In the Yala Swamp, all households rely on water extracted from the wetland for domestic use (Jansen and Schuyt 1998). In the same location, locals derive 86% of raw materials from the wetland, similar to Sabaki where residents depend upon the estuary and surrounding bush (within 2 km of the river) for more than 90% of raw materials collected. The reliance of local people on wetland materials is likely similar at other locations within Kenya, and governments should facilitate the protection and regulation of wetland resources to increase the security of the rural poor.

Water for domestic use has high availability but accessibility is variable. Water in the Sabaki River is not suitable for drinking, but is widely used for bathing, laundry, and washing in the household. To obtain drinking water, women carry water from bore holes and wells which are more than 2 km from the village centre. All water collection is performed by who expend considerable energy collecting water,reducing their time available to attain education, access health care, or participate in other income-generating activities (Cleaver and Donovan 1995). Water for livestock is mainly derived from the estuary, though cattle may be taken to freshwater pools in the wet season. The majority of those in the community who own cattle are dependent upon watering their livestock in the intertidal area.Because the cash income from sales is heavily dependent on livestock keeping and the availability of alternative sites for watering cattle is low, restricting use of the estuary for watering cattle would impact local livelihoods unless alternatives are introduced.

In Kenya, only 38% of the rural poor have access to clean drinking water sources (Suri et al. 2008). Providing piped water to human settlements ensures cleaner drinking water for communities and aligns with the Millenium Development Goal for governments of developing countries to halve the proportion of people without sustainable access to clean drinking water by 2015 (UNDP 2003). Provision of piped water would reduce the time women spend transporting water and reduce the need for livestock to seek water in the intertidal area. This solution facilitates community development and the management of human threats to waterbirds in this IBA.

Eco-tourism: realizing potential

Tourist visitation rates have increased by approximately 200% since 2006 when monthly visitation rates were estimated at 130 tourists/month (C. Jackson, unbpubl. data). The counts of tourists obtained in this study in fact represent a minimum estimate; although counts were fairly accurate, tourists entered the estuary from three main entry points (Appendix F). This required a co-ordinated effort to count all visitors and it is possible that some visitors were not counted.

The site support group at Sabaki, the Sabaki River Estuary Youth Group, comprises 50 members of which the majority are part-time, self-employed guides. Many foreign tourists visiting the Sabaki do so as part of guided tours which include visits to adjacent sites. Guides for these groups are sourced mainly in Malindi and local guides have difficulty securing clients and suffer from a sporadic income from guiding. Additionally, the lack of an entry fee or regulations regarding the activities of tourists in the estuary, presents a situation where the local community does not receive direct benefits from tourism and, furthermore, tourist activities may impact the local biota by causing elevated levels of disturbance to estuarine waterbirds (see Chapter 2). Tourism is a major source of income for impoverished peoples in the Coast province of Kenya, and contributes 6% of household income in Sabaki through local business and employment. Overall, the benefits received by the local community from the tourism industry could be improved, contributing to the local livelihoods and reducing pressure on estuarine resources and biodiversity.

Policies and frameworks for communal management of natural resources recognize communities as integrated components of the landscape (Agrawal and Gibson 1999). Current conservation activities in Sabaki Village, such as bee-keeping, demonstrate the willingness of locals to actively participate in conservation initiatives. The favourable response of community members towards increased tourism and regulation of resource extraction activities reflects the desire of the community to support a community-based reserve system at Sabaki River Mouth. These responses suggest that the local community will take custodianship over the estuary to facilitate the development of ecotourism activities.

The cost of managing Sabaki River Mouth IBA as a community-based reserve may be offset by revenue from tourism. If estuary use is restricted, substituting income from raw materials, fuelwood, crabs, and fish at Sabaki would be a monumental task given the reliance of people on the estuary for these materials (Table 3.1, Figure 3.3). Average per-capita household income in the coastal lowlands of Kenya was estimated as 112,892 KSh (1400 US$) in 2007 (Suri et al. 2008). On average at Sabaki, 56% of income is derived from natural resources, equating to an annual contribution of 156 000 US$ to household income from natural resources, Of that value, 22 700 US$ of household income is derived from fishing. The aggregate value of unrealized revenue from tourists willing to pay entry fees is a minimum estimate and could only approach partial substitution of the opportunity costs of restricting extractive activities if improvements to infrastructure were made or visitation rates increased. If an entry-fee system were introduced, the aggregate values for willingness to pay could be invested towards creation of a community reserve.

Although tourists scored possible road improvement as adding significantly to the value of their experience at Sabaki, the road into the estuary is more than 2 km in length and subject to frequent use by cattle and motorcycles, thus would require a significant initial investment in addition to the on-going cost of maintenance, which may exceed the value added by implementing better tourist infrastructure. The preferences of tourists to view fishers and cattle in the estuary show that these activities do not directly detract from the value of the area as a tourist destination. However, the presence of beach boys detracted from some visitors' experiences and developing initiatives which empower young males to attain education or salaried employment may reduce the numbers of beach boys in the estuary and contribute to livelihood security for these individuals.

Management recommendations

Future management of the estuary should focus on introducing sustainable harvest methods for fish, fuelwood, and charcoal, all of which represent important assets to households adjacent to the estuary. Management of tourist activities and improvement of the area for the value of tourists could be achieved by implementing a boardwalk, which would limit the movement of people across the tidal flats (thus reducing disturbance to foraging waterbirds) and simultaneously increase the revenue potential for the area. Given the dynamic nature of the intertidal area, constructing a boardwalk would be an undertaking requiring careful planning and should be located along the periphery of the estuary on the north bank. This is where tourist traffic is highest (Appendix F) and where mangroves and reeds would mitigate problems presented by seasonal flooding. Although most visitors to the estuary were non-birders, when interviewers explained that a bird hide would allow them to view birds from a concealed area, most visitors felt that it would enhance or strongly enhance their experience at the estuary. Thus, implementing a boardwalk and bird hide would contribute significantly to the value of the tourist experience at Sabaki and reduce movement of people across the intertidal flats. The costs of increased tourist infrastructure could be acquired through donor funding, and after formalization of an entry-fee, could be sustained as a community-based ecotourism project.

CHAPTER 4. Synthesis and future research needs

Synthesis

This study represents an integrated approach to identify conservation issues at a wetland of global significance to waterbirds and regional significance to the livelihoods of the rural poor in Kenya. Densities of foraging waterbirds were higher than observed densities in other intertidal areas, natural resources from the estuary and immediate surroundings contributed 56% of household income in an impoverished community of 2000 people, and hundreds of tourists and students visit the estuary each month. Thus, Sabaki estuary represents an important shared resource for birds and people and conservation of this area is pertinent. In combining an ecological and economic approach, this study bridges the research-implementation gap pervading traditional scientific method (Knight et al. 2008). The results of this study serve a dual purpose by creating an early knowledge-base essential to improve conservation of the Sabaki River Mouth IBA and through the evaluation of techniques for a rapid assessment of conservation issues in an east African context.

The method undertaken to assess the vulnerability of waterbirds to human disturbance represents a rapid technique for identifying vulnerable species when time and funds are of the essence. Concordance observed among the behavioural response variables for intertidal foraging waterbirds suggests that two metrics (bird density within a fixed radius of disturbance, and TR_{90}) can be utilized as surrogates in the place of three metrics. As in this study, simultaneous observation of these two metrics is possible, and thus this method is a cost-effective and rapid technique of deducing sensitivity of birds to disturbance. Disturbance did not appear to be a major threat to most focal species of waders, but likely degrades the quality of habitat for some species and more certainly for White-fronted Plovers. Greater Flamingos and Lesser Flamingos. Flamingos were especially sensitive to disturbance and harmful activities which create undue disturbance of these birds should be prevented for three reasons: i) Lesser Flamingos are Near Threatened (IUCN 2010) and thus of conservation concern, ii) the local population of Greater Flamingo is declining at Sabaki estuary, iii) flamingos are a tourist attraction and thus constitute an important component of tourism value of the Sabaki River Mouth IBA. Reducing disturbance levels in the estuary will locally mitigate some of the problems faced by birds in coastal wetlands in east Africa, including habitat loss and change.

The quantification of disturbance levels in the intertidal area revealed that the greatest sources of disturbance at Sabaki estuary were from livestock watering, fishing activity, and tourism. Provision of alternative watering sources or restricting areas where livestock are permitted would significantly reduce disturbance levels in some areas of the tidal flats. The construction of a boardwalk and bird hide could serve the dual purpose of restricting the movement of tourists into important foraging areas for birds, thus reducing disturbance, and increasing the tourism value of the estuary. Sustainable management of fishing activities should be of primary concern given that fishing is dispersed through the intertidal area and constitutes a potential source of disturbance to waterbirds, and practices known to be destructive are widespread. Unsustainable fishing practices (use of undersized nets, over-fishing) may threaten the persistence of fish stocks, which are an essential source of protein for local people. A small unrealized potential revenue exists for ecotourism at the estuary, and may substitute some opportunity costs associated with regulating resource use by local people. However, the level of integration between people and the land and the reliance of local people on natural resources is so substantial that conservation activities should aim to maintain sustainable levels of resource use by local people. Increasing tourism infrastructure will subsequently increase the value of the estuary as a tourist destination. Introducing an entry-fee system will stimulate economic development in the community through the positive diversification of livelihoods, however this must be undertaken with the co-operation of the Kenyan Wildlife Service, Department of Livestock, Ministry of Tourism, and Ministry of the Environment for the Government of Kenya.

A community-based approach to conservation of Sabaki River Mouth IBA can be achieved by creating the relevant networks between the IBA site support group (Sabaki River Estuary Youth Group), active NGOs at the site (A Rocha Kenya, Nature Kenya), and relevant sectors of government (mentioned above). Given the importance of the estuary to livelihoods on a regional-level and to waterbirds on an international-level, the government of Kenya should formalize protection of the estuary from overuse, illegal land-grabbing, and harmful tourist activities and facilitate the operation of a community-based reserve.

Future research needs

As the first examination of behavioural responses of waterbirds at a tropical African estuary, the conclusions regarding the vulnerability of species to disturbance are location-specific. Repeating these methods at other tropical wetlands where waterbird densities and human use-levels are high will provide insight into the vulnerability of waders to disturbance in tropical latitudes. Quantifying human activity in these same wetlands will allow cross-site comparisons of disturbance rates with the vulnerability of species and hence elucidate relationships between human densities and vulnerability of species to disturbance. In addition to providing information relevant to conservation of waterbirds at tropical latitudes, economic assessments of wetland use will increase the quantitative information regarding the value of wetlands. This information is vital for scientists to communicate the importance of wetlands to policy-makers, government, and civil society.

At Sabaki River Mouth, research is required to determine the impacts of habitat change on the resident waterbird population. Monthly counts over multiple years have been conducted and collection of soil core samples to estimate deposition rates will allow comparison of population trends with prey availability and sedimentation. As an internationally important site for gulls and terns, the occurrence of fishing by-catch mortality of terns at the IBA requires attention. Research is needed to determine the by-catch rates and determine which species are vulnerable to these activities. This will provide information key to managing threats to waterbirds at Sabaki River Mouth and other, similar tropical African estuaries.

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APPENDIX A. The top figure shows Important Bird Areas (IBAs - Mida Creek, Arabuko-Sokoke, and Sabaki Rver Mouth), national parks, reserves and major settlements on the central coast of Kenya. The study area at Sabaki River Mouth IBA is located approximately 10 km north of Malindi. The bottom figure is a zoomed satellite image of Sabaki estuary, located in Sabaki River Mouth IBA. Images modified from Google Earth (Google Inc. 2010).

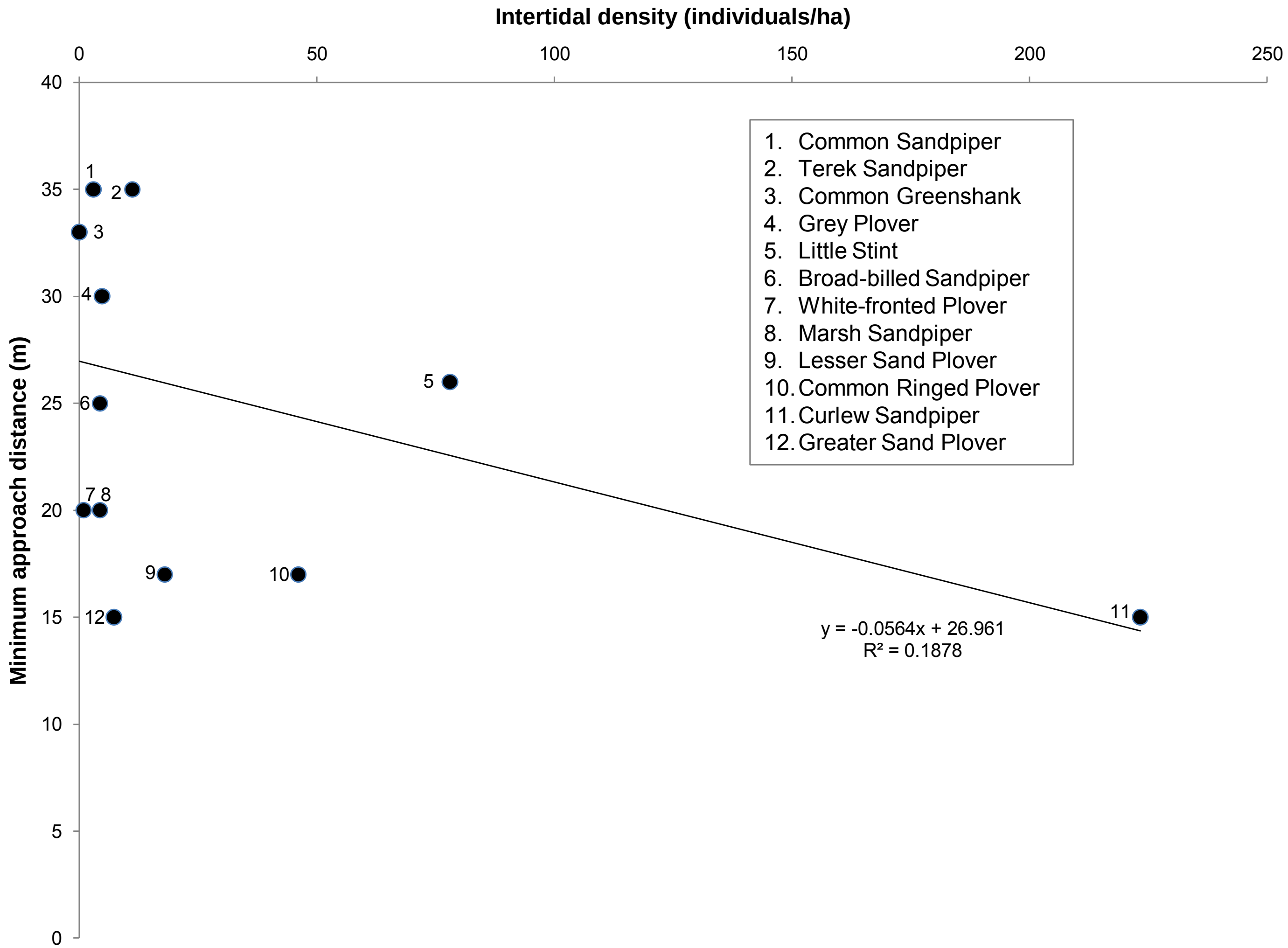
APPENDIX B. The intertidal waterbird community at Sabaki estuary, with estimated densities (birds/ha with ± 1 S.E.) from counts conducted at low tide (N = 4) on the neap tide cycle from September through November 2010. Also shown is the dominant activity of individuals in the intertidal area (F = foraging, R = roosting).

Family	Common Name	Scientific Name	Mean Density (birds/ha)	Dominant Activity
Accipitridae	African Fish-Eagle	*Haliaetus vocifer*	< 0.0	R
Alcedinidae	Grey-headed Kingfisher	*Halcyon leucocephala*	< 0.0	R
	Mangrove Kingfisher	*H. senegaloides*	< 0.0	R
	Malachite Kingfisher	*Alcedo cristata*	< 0.0	R
	Pied Kingfisher	*Ceryle rudis*	< 0.0	R
Anatidae	Egyptian Goose	*Alopochen aegyptiaca*	< 0.0	R
	Garganey	*Anas querquedula*	< 0.0	R
	Northern Pintail	*A. acuta*	< 0.0	R
	Fulvous Duck	*Dendrocygna bicolor*	0.3 ± 0.2	R
	White-faced Duck	*D. viduata*	2.4 ± 2.4	R
Anserinae	Spur-winged Goose	*Plectropterus gambensis*	< 0.0	R
	Grey Heron	*Ardea cinerea*	0.1±0.0	F, R
Ardeidae	Black-headed Heron	*A. melanocephala*	0.1±0.0	R
	Western Cattle Egret	*Bubulcus ibis*	< 0.0	R
	Dimorphic Egret	*Egretta dimorpha*	< 0.0	F, R
	Western Great Egret	*E. alba*	< 0.0	F, R
	Little Egret	*E. garzetta*	0.1 ± 0.0	F, R
	Yellow-billed Egret	*E. intermedia*	< 0.0	F, R
Burhinidae	Spotted Thick-knee	*Burhinus capensis*	< 0.0	F, R
	Water Thick-knee	*B. vermiculatus*	< 0.0	F, R
Charadriidae	Grey Plover	*Pluvialis squatarola*	2.2 ± 0.2	F
	Greater Sand Plover	*Charadrius leschenaultii*	2.6 ± 0.5	F
	Kittlitz's Plover	*C. pecuarius*	< 0.0	F

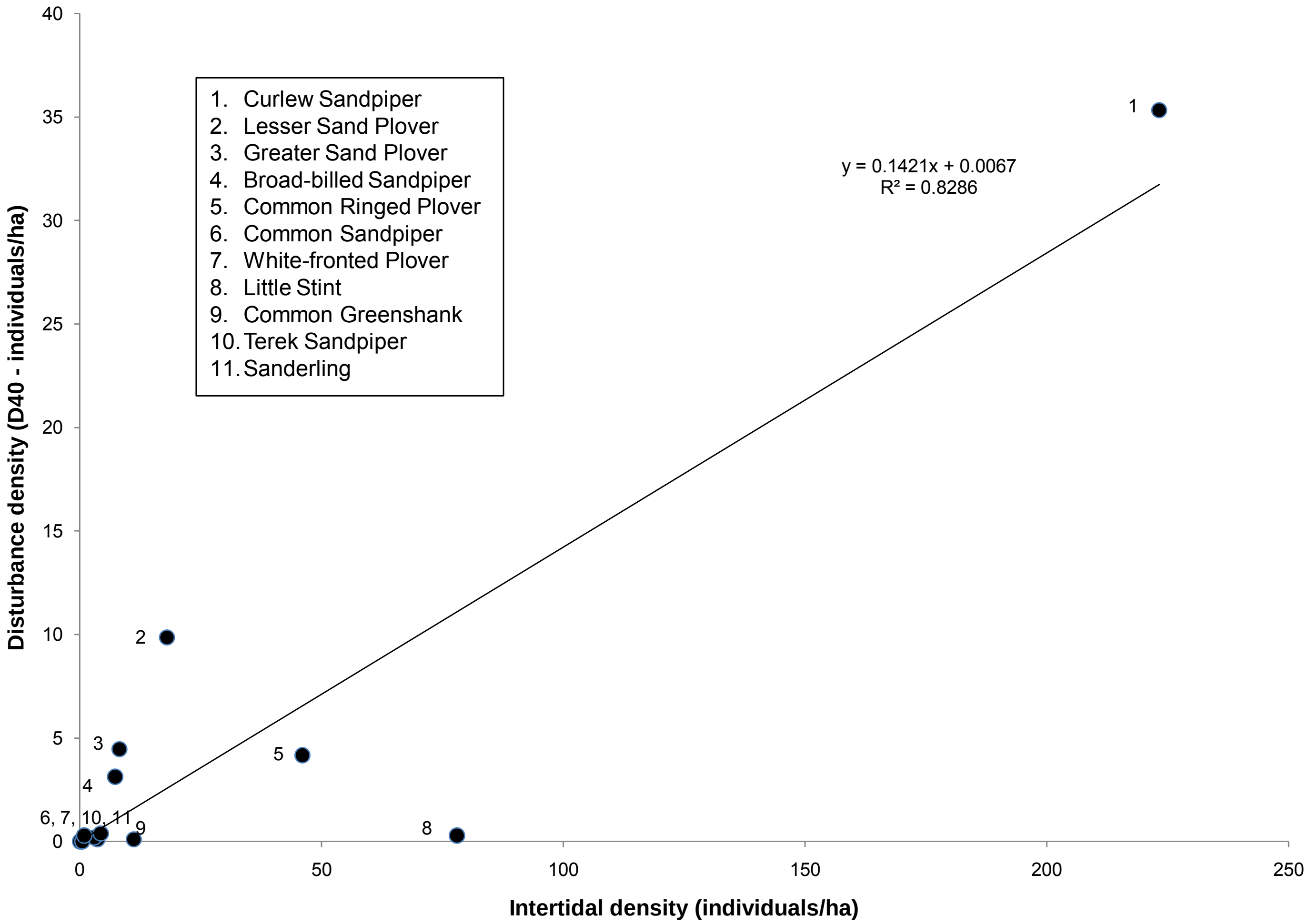
Charadriidae	Lesser Sand Plover	*C. mongolus*	5.5 ± 2.3	F
	Common Ringed Plover	*C. hiaticula*	10.8±2.7	F
	Three-banded Plover	*C. tricollaris*	< 0.0	F
	White-fronted Plover	*C. marginatus*	0.6±0.2	F
	Spur-winged Plover	*Vanellus spinosus*	2.5 ± 0.5	R
Ciconiiadae	African Openbill	*Anastomus lamelligerus*	< 0.0	R
	Marabou Stork	*Leptoptilos crumeniferus*	< 0.0	R
	Woolly-necked Stork	*Ciconia episcopus*	< 0.0	R
	Yellow-billed Stork	*Mycteria ibis*	0.2 ± 0.1	F, R
Dromadidae	Crab Plover	*Dromas ardeola*	< 0.0	F
Glariolidae	Collared Pratincole	*Glareola pratincola*	< 0.0	R
	Madagascar Pratincole	*G. ocularis*	< 0.0	R
Laridae	Lesser Black-backed Gull	*Larus fuscus*	0.3 ± 0.2	R
	Sooty Gull	*Ichthyaetus hemprichii*	3.1 ± 2.7	R
Pelecanidae	Great White Pelican	*Pelecanus onocrotalus*	< 0.0	R
	Pink-backed Pelican	*P. rufescens*	0.4 ± 0.2	R
Phoenicopteridae	Greater Flamingo	*Phoenicopterus roseus*	2.9 ± 0.9	F
	Lesser Flamingo	*Phoenoconaias minor*	2.5 ± 0.5	F
Pandionidae	Western Osprey	*Pandion haliaetus*	< 0.0	R
Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	< 0.0	F
	Black-winged Stilt	*Himantopus himantopus*	< 0.0	F
Rhyncopidae	African Skimmer	*Rynchops flavirostris*	< 0.0	R
Scolopacidae	Terek Sandpiper	*Xenus cinereus*	2.7 ± 0.6	F
	Broad-billed Sandpiper	*Limicola falcinellus*	2.2 ± 0.2	F
	Marsh Sandpiper	*Tringa stagnatilis*	1.0 ± 0.3	F
	Common Greenshank	*T. nebularia*	2.5 ± 0.4	F

Scolopacidae	Common Redshank	*T. totanus*	< 0.0	F
	Green Sandpiper	*T. ochropus*	< 0.0	F
	Wood Sandpiper	*T. glareola*	0.1 ± 0.0	F
	Common Sandpiper	*Actitis hypoleucos*	1.0 ± 0.3	F
	Curlew Sandpiper	*Charidrus ferruginea*	52.2 ± 12.7	F
	Little Stint	*C. minuta*	19.7 ± 5.8	F
	Sanderling	*C. alba*	0.1 ± 0.1	F
	Eurasian Curlew	*Numenius arquata*	0.1 ± 0.0	F
	Common Whimbrel	*N. phaeopus*	0.3 ± 0.1	F
	Bar-tailed Godwit	*Limosa lapponica*	< 0.0	F
	Ruddy Turnstone	*Arenaria interpres*	<0.0	F
	Ruff	*Philomachus pugnax*	< 0.0	F
Sternidae	Caspian Tern	*Hydroprogne caspia*	0.6 ± 0.3	R
	Common Tern	*Sterna hirundo*	2.0 ± 2.3	R
	Roseate Tern	*S. dougallii*	< 0.0	R
	Saunders's Tern	*S. saundersi*	1.8 ± 2.4	F, R
	Greater Crested Tern	*Thalasseus bergii*	0.7 ± 0.5	R
	Lesser Crested Tern	*T. bengalensis*	4.7 ± 3.0	R
	Gull-billed Tern	*Gelochelidon nilotica*	1.7 ± 0.4	F, R
Threskiornithidae	African Spoonbill	*Platalea alba*	1.0 ± 0.6	F
	Sacred Ibis	*Threskiornis aethiopicus*	0.5 ± 0.2	F, R

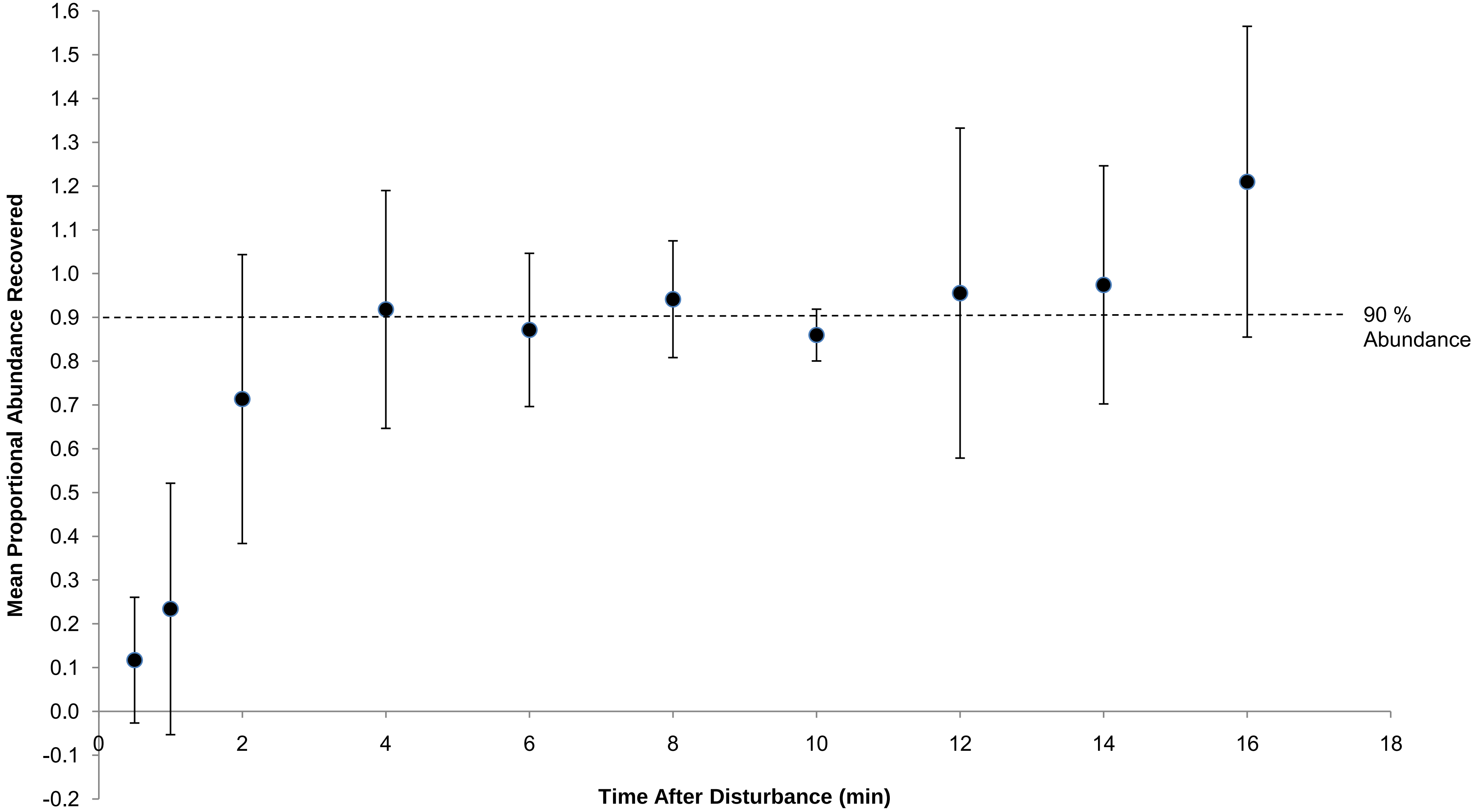
APPENDIX C. Mean density on the whole flat versus minimum approach distance within a 40 m radius of stationary disturbance for one site within the intertidal mudflats at Sabaki estuary. The slope of the regression line represents the mean distance response of birds to disturbance relative to their density in the absence of disturbance.



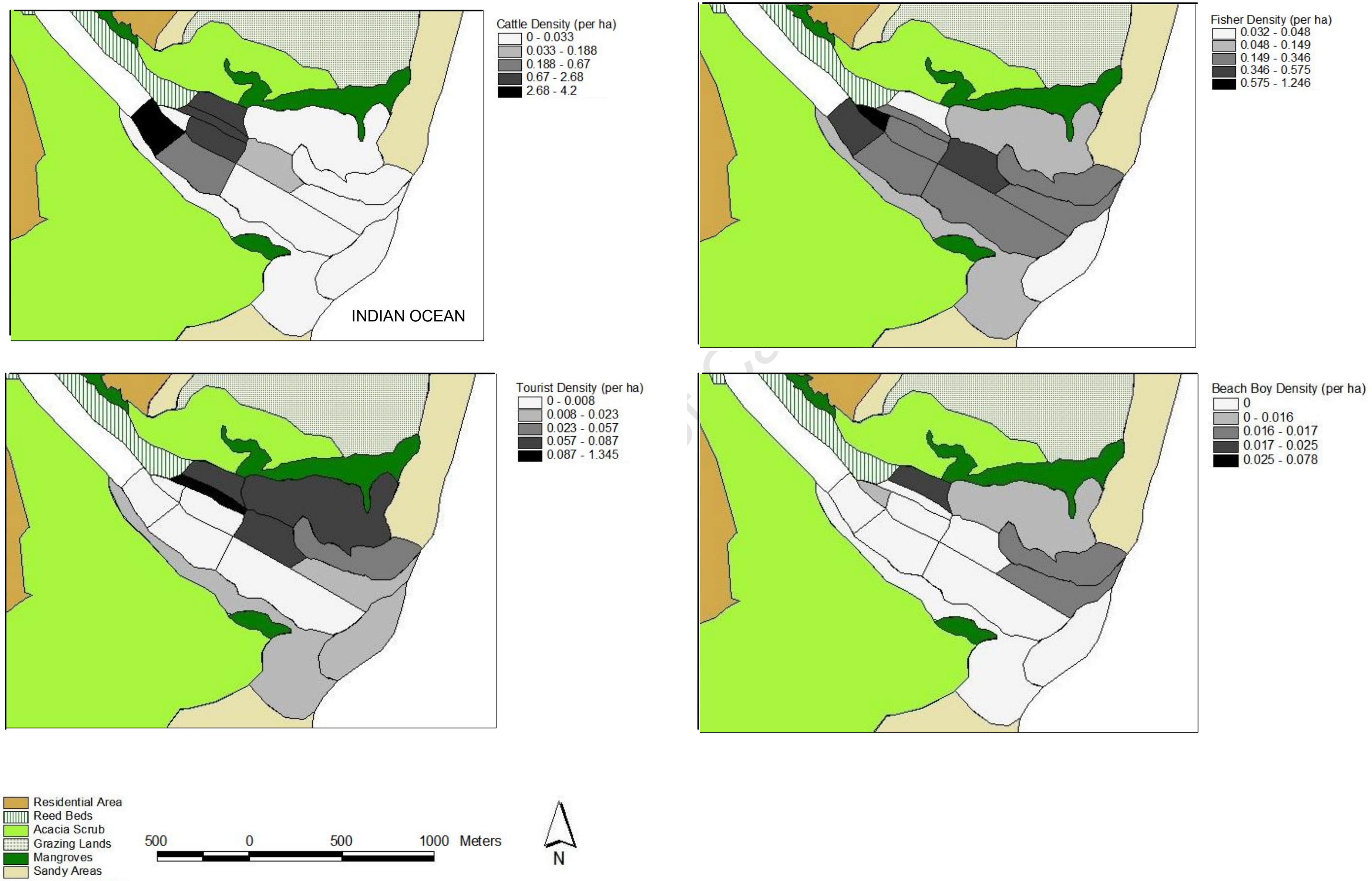
APPENDIX D. Mean density on the whole flat versus mean density within a 40 m radius of stationary disturbance for one site within the intertidal mudflats at Sabaki estuary. The slope of the regression line represents the mean density response of birds to disturbance relative to their density in the absence of disturbance.



APPENDIX E. Mean recovery in abundance with error bars showing ±following disturbance for Common Ringed Plover at Sabaki estuary estimated as means from 15 recovery time experiments. Time to recovery 90% of original abundances (TR_{90}) was estimated as the interval at which the average proportion of original abundance was equal to 0.90.



APPENDIX F. Sources of disturbance and accompanying densities in the intertidal and adjacent sandy areas of Sabaki estuary.



APPENDIX G. Focal waterbird species defined as those species appearing more than twice within 40 m of simulated stationary disturbances (N = 20) at Sabaki River Mouth. Shown are the mean minimum distances (± 1 S.E.) of species from simulated stationary disturbances and the number plots in which the species was observed (N).

Family	Common Name	Minimum approach distance (m)	N
Phoenicopteridae	Greater Flamingo	35.3 ± 3.1	6
	Lesser Flamingo	38.3 ± 3.3	3
Charadriidae	Common Ringed Plover	22.0 ± 2.3	18
	White-fronted Plover	26.3 ± 2.1	6
	Lesser Sand Plover	26.3 ± 2.5	13
	Greater Sand Plover	24.8 ± 2.4	17
	Grey Plover	28.3 ± 2.2	4
Scolopacidae	Curlew Sandpiper	24.4 ± 2.4	19
	Little Stint	23.4 ± 2.4	12
	Terek Sandpiper	32.5 ± 2.5	3
	Common Greenshank	28.6 ± 2.7	8
	Marsh Sandpiper	27.5 ± 2.5	5
	Common Sandpiper	24.7 ± 2.2	5
	Broad-billed Sandpiper	23.6 ± 2.1	8

APPENDIX H. Questionnaire used for household interviews between 15 October and 25 November 2010 in Sabaki Village.

Interviewer: ____________________________

Date: __________________________________

Sabaki Household Questionnaire – Estuary Use

1. How many are in your household (those that eat from the same pot)? ____________________

2. I would like you to describe sources of income for this household. Imagine this pile beans represents all the income that your household gets in one year. Income includes money, food, fuel, and water collected for use in the household. This does not include bought or purchased items. Please show me where the household income comes from by putting the beans on the different pieces of paper.

3. For *livestock, crops*, *natural resources*, and *water,* what proportion of this income is derived from the Sabaki, including the estuary and adjacent bush within 2 km of the river?

4. For handicrafts, employment, and other business, how much of the income is derived from tourism (e.g. sales to local and foreign visitors)?

Type		**Total**	**From Sabaki**	**From Sales**
Own production	Livestock			
	Crop products			
	Handicrafts			
	Harvested raw materials			
	Charcoal			
	Fuelwood			
	Fish & Prawns			
	Crabs & Vongoles			
Water				
Employment				**Tourism**
Other business/ trade				
Remittances			-	-
Pension and government welfare			-	-

5. Would you benefit from increased tourism in the estuary?

Yes / Partly / No / Unsure

6. Do you think farming and resource extraction activities should be regulated in the estuary?

Yes / Partly / No / Unsure

7. Where do you do most of your fishing? (Circle those that apply)

River Mouth / Middle Estuary / River Banks / Mangroves

8. What kind of fishing do you do? (Circle one)

Mostly with net / Both line and net / Mostly with line / Mosquito Net

9. What type of livestock are kept at Sabaki and how many?

____

____

10. Where do you use water from? (Circle those that apply)

Mostly dunes / Both dunes and river / Mostly river / Freshwater pools

11. What leisure, cultural, or spiritual activities do you use the estuary for?

____

____

12. Does the household use the estuary for any of the following?
13. What is the availability of alternative areas for this activity?

	12. Yes / No	13. Availability of alternatives		
		Low	Med	High
Fishing		☐	☐	☐
Livestock watering		☐	☐	☐
Leisure		☐	☐	☐
Cultural/spiritual activities		☐	☐	☐
Water extraction		☐	☐	☐
Medicinal plant collection		☐	☐	☐

APPENDIX I. Questionnaire used for face-to-face interviews of tourists to the estuary between 4 October and 6 November 2010 at Sabaki estuary.

Date:__________________________

Interviewer:_____________________

SABAKI VISITOR QUESTIONNAIRE

I'm working for a Master's student from the University of Cape Town who is conducting a study on what attracts people to this estuary and how ecotourism could be improved here. Would you mind answering some simple questions regarding your visit to Sabaki? ... approx. 10 minutes

1. Where are you from? ______________________________________ (City, Country)

2. What were you hoping to see? (tick *only* those that apply)

BIRD-WATCHERS: Rarity ☐ Diversity ☐ Abundance ☐

Bush Birds ☐ Waterbirds ☐

ALL VISITORS: Flamingos ☐ Hippos ☐ Scenery ☐ The People of Sabaki ☐

3. Does the presence of cattle enhance or detract from your experience (circle one)?

   Enhance / Neutral / Detract / Does not apply

4. Does the presence of fishers & nets enhance or detract from your experience (circle one)?

   Enhance / Neutral / Detract / Does not apply

5. Does the presence of beach boys enhance or detract from your experience (circle one)?

   Enhance / Neutral / Detract / Does not apply

6. What is the most you would pay for an entrance fee (excluding guide fees)?

   In Kenyan Shillings: 0 / 20 / 50 / 100 / 200 / 500 / 700 / 1000 / 2000 / More ____

7. Would the following subtract from or add to the value of your experience?

	Strongly subtract	Subtract	Neutral	Add to	Strongly Add to
Bird hide	☐	☐	☐	☐	☐
Boardwalk	☐	☐	☐	☐	☐
Interpretive signage	☐	☐	☐	☐	☐
Visitor's centre	☐	☐	☐	☐	☐
Presence of rangers	☐	☐	☐	☐	☐
Improved road	☐	☐	☐	☐	☐
Café	☐	☐	☐	☐	☐

8. If those that would add to your experience where in place, what is the most you would pay for an entrance fee (excluding guide fees)? (circle one)

   In Kenyan Shillings: 0 / 20 / 50 / 100 / 200 / 500 / 700 / 1000 / 2000 / More ____