

Sightings, Incidental By-Catch, and Hunting of Dugongs (*Dugong dugon*) on the West Coast of Madagascar, as Inferred from Interviews with Local Fishers: Evidence for Decline in Populations due to Human Exploitation

Salvatore Cerchio, Norbert Andrianarivelo and Boris Andrianantenaina
Wildlife Conservation Society, Ocean Giants Program

2300 Southern Blvd, Bronx, NY, 10460, USA

B.P. 8500 Soavimbahoaka, Antananarivo 101, MADAGASCAR

Correspondence: scerchio@wcs.org

ABSTRACT

There exists little current information on the distribution and status of the dugong (*Dugong dugon*) in Madagascar. In order to provide recommendations for more effective dugong conservation, we report here on data from the west coast of Madagascar relating to dugongs, drawn from a more taxonomically comprehensive study. Interview surveys with Malagasy fishers, aimed at gathering traditional knowledge and information on hunting and by-catch of all marine mammals, were conducted in 58 villages in 13 locations along the west coast of Madagascar from Nosy Mitsio in the northwest to Ifaty in the southwest. During five different expeditions between 2008 and 2011 we interviewed a total of 712 fishers during 210 interview sessions. Given the larger context of the study, targeted regions did not necessarily represent areas where dugongs had been previously reported, and several notable locations were not included in the sampling. Nevertheless, the data represent new information from geographically disparate regions. There were a total of 533 reports of dugongs spread across 6 decades, with 318 reports of ‘hunting’, 110 reported ‘by-caught’, 101 reported sighted ‘live’ and four reported ‘stranded’. Dugongs were reported geographically widespread from the northwest to southwest, with the highest numbers among our sampled locations reported in the southwest locations of Bevato and Andavadoake, the mid-west location of the Barren Islands, and the northwest location of Nosy Mitsio (in declining order of reports). There is evidence for a decline in numbers of sightings and individuals captured in hunting and by-catch during the most recent decade (2000-2010), and shifts in the relative distribution of reports over time, suggesting that populations in some locations may be more impacted or near extirpated. We recommend prompt conservation action is needed in order to conserve the remaining populations and mitigate further impacts from continued hunting and by-catch.

Citation: Cerchio S, Andrianarivelo N, Andrianantenaina B. 2012. Sightings, incidental by-catch, and hunting of dugongs (*Dugong dugon*) on the west coast of Madagascar, as Inferred from Interviews with Local Fishers. Report to the Convention on Migratory Species. 17pp.

INTRODUCTION

Dugongs (*Dugong dugon*) are the sole extant species in the family Dugongidae in the aquatic mammalian order Serinia. The species is widely distributed in tropical and sub-tropical Indian Ocean and western Pacific Ocean, occurring in coastal waters of 48 countries range-wide (Marsh 2008). Currently the IUCN Red List status is Vulnerable, however the true status throughout much of the range is unknown and many or most populations are thought to be threatened due to overexploitation (Marsh et al 2002, Marsh 2008).

At least two regional populations are thought to be extinct, in Mauritius and Taiwan, China (Marsh 2008, C3 Madagascar and Indian Oceans Islands Programme 2010a). Most current information on dugongs in coastal waters of Madagascar is based on unpublished reports and anecdotal communications (Cockcroft 1993, Cockcroft & Young 1998, WWF Eastern African Marine Ecoregion (WWF-EAME) 2004, C3 Madagascar and Indian Oceans Islands Programme (C3-MIOIP) 2010b, see Cooke et al. 2003). They are known to occur throughout Madagascar with uncertain population status, but believe to be heavily exploited to the point that sightings of live animals are very rare (Cooke et al. 2003, Rosenbaum 2003). Cook et al. (2003) reports sightings and captures during the 1990s and as recent as 2000 in the north, northwest, central west, southwest and northeast regions, indicating the Masoala Peninsula/Antongil Bay in the northeast, and Ampasindava in the extreme north as being areas with highest incidence of recent sightings (also reported by Rosenbaum 2003). However, Cooke et al (2003) also indicate that dugongs are now absent or rare in areas where they were once frequently reported, such as the Bay of St. Augustine in the southwest, and around Soalala and the Nosy Be region in the northwest, suggesting local extirpation in portions of their original range. WWF-EAME (2004) reported that populations appeared to have declined rapidly since the 1980s, and suggest several areas in the northwest, central west, southwest and northeast as important for dugong although with generally sparse populations. More recently, there have been reports in the northwest of Madagascar from interview surveys in the Diana region north of Nosy Be (C3-MIOIP 2010b), although the study also reports population decline since the 1990s. There have also been at least a few recent reports in the northeast in Antongil Bay (Wildlife Conservation Society 2012). There are very few observations of live animals in any study, however aerial surveys for marine megafauna recently documented several live sightings along the northwest coast between Mahajanga and Bay of Sahamalaza in December 2009 (Van Conneyst et al. 2010). Our study adds to this accumulating evidence, and reports on the distribution and status of dugongs along an extended length of the west coast of Madagascar, based upon interview surveys with local fishers.

METHODS

Socio-economic interview surveys were conducted in villages on the west coast of Madagascar between 2008 and 2011. Surveys targeted fishers in coastal villages and were aimed at collecting information about the occurrence, hunting and by-catch of all marine mammals, with a focus on collecting data on the prevalence of previously documented coastal dolphin hunting and by-catch (Andrianarivelo 2001, Cerchio et al. 2009, Razafindrakoto et al. 2009); however, only results collected on dugongs are reported here. Since hunting of marine mammals is illegal in Madagascar, and this is widely known among west coast communities that practice dolphin hunting in particular, the collection of data regarding hunting and by-catch of marine mammals is a very sensitive topic. Therefore, several protocols were followed aimed at creating a relaxed atmosphere and gaining the confidence of interviewees. The interview team leader (NA) has extensive experience conducting interviews with fishers in Madagascar and working with coastal communities since 1999. Interviews were conducted by an all Malagasy team, always including one member from the general region, and when possible a local fisher or mariner from the area that was known among the targeted villages (typically hired at the specific site). The absence of westerners/foreigners (or Vazaha in Malagasy), and the presence of a known local individual, allowed the interviewees to feel at ease, allaying suspicions and encouraging honest responses. We avoided a clinical approach and the use of forms or creating hardcopy documentation in the presence of fishers. Instead we have developed an informal, standardized set of questions that are delivered in a casual verbal manner. Interview sessions (each of which is considered a sample) took the form of interviews with single individuals, or focus groups, where a group of related fishers were interviewed. Questions were designed to gather (a) village/population information, including number of fishers, gender and age breakdown, backgrounds and types of activities practiced; (b) individual information, including age, family size, areas fished and types of gear used; (c) information on marine mammals in the area, including species found (using a visual guide with French, English, and Malagasy names), frequency of encounter, and areas observed; and (d) information on by-catch and hunting, including: whether marine mammals were ever

incidentally entangled in gear; when caught as by-catch, how often they were consumed or released; whether there was active hunting for marine mammals, and if so, how frequently it occurred, how many individuals were taken, and what was done with the meat (distributed locally or sold at markets).

Due to the rapid nature of the survey missions and often short time available at any given village, it was not possible to make a standardized random sampling of all households in a village. Instead, a haphazard approach was used, approaching individual fishers as they returned from sea, or organizing a focus group in a similar manner (approaching groups of fishers that were already gathered). Age of the interviewees was estimated within decadal categories by the interviewers, and data was collected regarding the type of fishing they engaged in and the gear used. During an interview, a fisher was asked to report any observations that he/she, or the group, knew of involving marine mammals, including dugongs, and was presented with a detailed full-color visual guide developed by the Wildlife Conservation Society that contains highly detailed illustrations meant to be used for field identification. Reports were categorized as one of four different event types: hunting, by-catch, stranding, or live sighting. For hunting and by-catch events, the type of fishing gear was recorded along with if and how the dugong meat was used (i.e., consumed, sold). The number of individual dugongs in each event was recorded, along with the timing of the event by the year of occurrence. In cases where the fisher could not remember the exact year, the interviewers approximated the year by associating the event with some landmark in the life of the fisher (e.g., marriage, birth of a child, etc). For purposes of assessing trends, events were grouped into decades from the 1950s (1950-1959) to the 2000s (2000-2010; in only this most recent decade, the decadal year 2010 was grouped with the previous decade, resulting in essentially an “11-year decade”). To evaluate more recent trends, events in the 1990s and 2000s were also grouped into four periods, 1990-1994, 1995-1999, 2000-2004, and 2005-2010.

For the purposes of reporting results, surveyed villages in close proximity were grouped into separate “locations” (Figure 1). In the northwest of Madagascar, interviews were conducted at three locations, the islands of Nosy Be and Nosy Komba (hereafter referred to as simply Nosy Be; 8 villages), the island of Nosy Faly and the nearby “Grande Terre” (the main land of Madagascar, hereafter referred to as Nosy Faly/GT; 5 villages), and the island of Nosy Mitsio (18 villages). During September 2008, interviews were conducted on an opportunistic basis while stationed on Nosy Komba for boat-based surveys of coastal cetaceans. During September 2009, a directed mission was planned to survey villages around Nosy Be and to the immediate east on Nosy Faly/GT. Villages were chosen to provide a geographically representative sampling from the region within the available time. During August 2011 a directed mission was planned to survey villages on Nosy Mitsio, with an effort to sample as many as possible of the 24 small villages on the island. In the southwest and central west coast of Madagascar, 13 locations were surveyed in 2010. From August to October 2010, during a long-range sailing vessel-based survey to assess offshore waters for cetaceans, originating in Toliara and ending in Mahajanga, short stops were made at 10 locations for one to three days each. Interviews were conducted, from south to north, at Ifaty (4 villages), Andavadoake (4 villages), Morombe (2 villages), Belo sur Mer (3 villages), Morondava (2 villages), Ambozaka (1 village), the Barren Islands (3 villages) and Mahajanga (4 villages). In December 2010, a mission was conducted to visit several villages in the general Andavadoake region, that were reported in the previous expedition to engage in dolphin hunts; these included surveys conducted in the locations Bevohitse (3 villages) and Bevato (1 village), as well as additional surveys in Andavadoake.

RESULTS

Among the thirteen regions (locations) surveyed, we visited a total of 58 villages and interviewed 712 fishers during 210 interview sessions (Table 1). Estimated population size, summed for each location among only the villages surveyed, varied widely, from 14,170 in Nosy Be to 60 in the Barren Islands; thus the estimated percentage of fishers interviewed varied similarly from a low of 1% to high of 40% (Table 1). Estimated age of interviewees ranged from 15 to 80 (children under 15 were not considered in

the interviews), with a modal age of 31-40 years representing nearly 30% of all interviewees (Figure 1). There was a considerable drop in the numbers of interviewees older than 50, which clearly impacts the historical reports of dugong presence.

There were a total of 533 reports of dugongs spread across all years and categories of report (Table 2). The report category with the highest numbers was 'hunting' with a total of 318 reports, with fewer numbers reported sighted 'live' or 'by-caught' (110 and 101, respectively) and very few 'stranded' (only four). Dugongs were reported geographically widespread from the northwest to southwest (Table 2, Figure 2, 3 and 4), with the highest numbers reported in the southwest locations of Bevato and Andavadoake, the mid-west location of Barren Islands, and the northwest location of Nosy Mitsio (in declining order of reports; Table 2). In some locations, dugongs were reported only prior to 2000 (Ambozaka and Nosy Faly/GT; Figure 2) suggesting that they may have historically occurred but have been extirpated from these areas. In other locations, dugongs were not reported at all (Nosy Be, Morondava, Morombe and Ifaty; Figure 2) suggesting that they may never have been common in these areas and that distribution along the west coast is historically heterogeneous; however, at least one of these locations (Morombe) is relatively close to locations with many reports (Bevato and Andavadoake), so absence of reports should be interpreted with some caution. Within locations there was variation in incidence of reports among different villages. In Nosy Mitsio, interviewees from half of the surveyed villages did not report any dugongs, whereas several reported dugongs only prior to 2000, and interviewees in two villages reported by-catch in the period 2000-2004 (Figure 3, Table 2); there were no reports of hunting, and no reports at all from 2005-2010 in Nosy Mitsio. In the Barren Islands there were reports of both hunting and live sightings in two of the three surveyed villages (Figure 4). In Belo sur Mer there were recent reports of live sightings on the mainland village, but no reports at all on two small islands off the coast (Figure 4). There were reports of recent hunting in nearly all villages surveyed in the Bevato, Andavadoake and Bevohitse locations (Table 3, Figure 4). In the southwest locations and the Barren Islands mortality from hunting was generally far more prevalent than by-catch, in contrast to the northwest locations from Mahajanga to Nosy Mitsio where by-catch was the more prevalent reported mortality (Table 2).

Considering temporal trends, we summed reports from all locations into decadal periods and also assessed the 1990's and 2000's in greater detail (Figure 5). There is a steady increase in the numbers of dugongs reported from the 1950s to the 1970s (Figure 5a), which is likely due to a combination of the effects of interviewee memory (with fewer older events remembered) and the reduced numbers of older interviewees able to report 40 to 60 years in the past (see Figure 1). Thus the apparent increase in reports during the first 3 decades is almost certainly an artifact due to the nature of interview surveys. There is a slight increase in reports in the 1990s, also possibly an artifact due to an interviewee memory effect, and then a drop in reports during the 2000s. These trends are similar when considering all reports combined (Figure 5a), or only reports of dugongs killed in hunting or by-catch events (Figure 5c). When looking in more detail at the past 20 years, there is evidence that the decline in reports and hunting/by-catch is most marked in the past six years from 2005-2010, with a number of reports that is less than half of the peak five-year period of 1995-2000 (Figure 5b and d). Almost all recent reports (2005-2010) are from the southwest locations of Bevato, Andavadoake and Bevohitse, with only two additional reports (by-catch) in the Mahajanga villages; in the previous five years (2000-2004) reports were made in the additional locations of Nosy Mitsio, Barren Islands and Belo sur Mer, none of which reported more recently (Table 3). In order to compare among regions, the numbers reported were standardized by the number of interviewees, producing rates of number of dugong reports per interviewee (Figure 6); the reported trend suggests that the relative prevalence of dugongs among regions has shifted with the Barren Islands being much more important prior to 2000 than it is currently, and the three southwest locations mentioned above maintaining a relatively high reporting rate into the 2000s.

A total of 243 reports of hunting and 100 reports of by-catch were accompanied by information on the gear used during the event. Nearly all hunting (99.6%) events were done with harpoon. All by-catch events were made with nets, with 48% of captures made with “ZxZ”, a large mesh (8-10 cm) gillnet, and 37% of captures made with “Jarifa”, a very large mesh (12-25 cm) gillnet, both used primarily for large pelagic fish and shark (Gough et al. 2009). In all cases where information was collected on the use of dugong meat, interviewees reported direct consumption and local sale in their home village or near-by villages. This is noteworthy particularly for by-catch in areas where there was no (or little) hunting reported, such as Nosy Mitsio; although dugong are apparently not targeted in such areas, the meat is considered edible and desirable.

DISCUSSION

There are several noteworthy considerations in the interpretation of the reported interview data. The finding of a steady decrease in reports, particularly of hunting and by-catch, during the last two decades is alarming because it goes against the bias expected in interview surveys. Since recent memories of sightings and catches are more easily recalled by the interviewee, it is expected that there would be inflation in reports from recent years (or a deflation bias in the more distant years); however, the collected interview data clearly goes counter to this expected bias, suggesting that the decrease in reports reflects a real trend in the population of dugongs. Furthermore, our data suggest that the decline may be substantial in the very recent past, with numbers of dugongs declining markedly in the past 10 years (2000-2010). Geographic variation in reporting suggests that some areas that we surveyed, such as the Barren Islands, may have had larger populations of dugongs in previous decades, that no longer appear to be prevalent, possibly due to overexploitation (in the case of the Barren Islands, supported by the high number of reports of hunting prior to 2000). Most importantly, there appear to be no “refuges” within the locations we surveyed, since the locations with the highest recent reports (locations in the southwest) are also locations with the highest reports of recent hunting and by-catch. No locations reported high numbers of live sightings without high incidence of mortalities due to hunting and by-catch.

In comparing our data with previous reports on dugong occurrence and status in Madagascar, we find both congruent and differing information. A 2003 interview study on dugong status (WWF-EAME 2004) indicated that the Andavadoake and Morombe regions were among the most important areas for dugongs, documenting both live sightings and recently hunted animals. This reinforces our findings of historic and recent dugong hunting in this region (specifically in Bevohitse, Andavadoake and Bevato); however, it should be noted that this is also an area of intensive socio-economic surveying and community intervention (at least Andavadoake), so it is possible that these communities are “primed” to respond positively to surveys. Since the WWF-EAME (2004) survey occurred in 2003, seven years prior to ours, the potential effect may have been less during those interviews, providing some reassurance regarding the reliability of the more recent responses in our interviews. Furthermore, our interview survey did not specifically ask about dugongs, but requested information on all marine mammals with a focus on dolphins. Therefore, all information gathered on dugongs was offered up voluntarily by interviewees upon being presented with a list of possible species on a high quality visual guide. In addition, the pattern of responses indicated that those fishers that reported on dugongs were not the same that reported most extensively on dolphin hunting. Thus there is evidence for specialization in hunting behavior among different fishers (see below for further discussion). We therefore have reason to consider the reports from the southwest Bevohitse, Andavadoake, and Bevato locations to have some veracity, and until proven otherwise the region should be regarded as potentially important for dugongs, and an area where there has been very recently active depletion of the remaining extant population.

In the northwest, our survey location of Nosy Faly was also one of four locations surveyed in C3-MIOIP (2010b), and as in our study all sightings were prior to 2000, with no recent reports. Interviewees in the C3-MIOIP (2010b) study reported a decline in dugong abundance between 1982 and 2006, which is also

similar to our findings; however, the greatest decline in the C3-MIOIP (2010b) study was perceived by interviewees to be in the late 1980s to early 1990s. This contrasts with our data suggesting that the greatest decline occurred more recently during the 2000s; potential explanations for this could be differences in the region covered since most information on hunting in our study came from the southwest, or to differences in methodologies, since the previous report was gauging fishers' perceptions, while we were inferring from the timing of reports recollected by interviewees (and it is unclear which could be more accurate). Another notable difference between our results and C3-MIOIP (2010b) is that the prior study indicated that about half of reports (54%) were of dead dugongs and half live sightings; conversely, our data indicated that only 20% (110 of 533) of reports were of live dugongs, so reports of hunting and by-catch were fully four times greater. Again this may be attributable to the different regions covered, and it is noteworthy that reports of hunting in our study were nearly absent among the northwest locations (Mahajanga, Nosy Be, Nosy Faly/GT, and Nosy Mitsio) where the Sakalava people are the most common ethnicity, whereas reports of hunting were highly prevalent in southwest among the Vezo people that have been otherwise documented as ardent dolphin hunters (Andrianarivelo 2001, Cerchio et al. 2009). But the difference in percentage of hunting reports with C3-MIOIP (2010b) may also be due to the style of interview survey. It is possible that the relaxed atmosphere that we attempted to create with only Malagasy interviewers and the absence of written documentation during the interview effectively made the interviewees more at ease and willing to report hunting; if this were to be accurate, than the incidence of hunting and by-catch reported by C3-MIOIP (2010b) may be underestimated.

In some villages, a large percentage of the hunted dugong numbers came primarily from a few fishers that reported large numbers. There were five interview sessions in which more than 10 dugongs were reported hunted and accounted for 65% of the total individuals hunted: in Bevato, a single fisher that described himself as a turtle hunter reported killing at least 50 dugongs from 1954 to 1995; this same fisher in Bevato reported at least 30 dugong hunted by other fishers at undetermined dates; in Andavadoake, a small focus group of two fishers reported hunting 25 dugongs from 1990 to 2009; in the Barren Islands two focus groups of eight and two fishers each reported hunting 50 dugongs from 1960 to 2000, and 1950 to 2000, respectively. The remaining 35% of total individuals hunted were attributed to 53 reports of less than 10 individuals. Conversely, reports of by-catch were more evenly distributed, with only three interviews reporting ten dugongs, accounting for 30% of individuals reported by-caught; the remainder of reports consisted of three reporting five dugongs, and 50 reporting either two or one dugong by-caught. The five interview sessions that reported high numbers hunted contribute disproportionately to the observed trends, which may be considered a reason for caution. However, it also appears that there is a tendency for some fishers to learn the behavior of dugongs and techniques for hunting them, and thus may in reality contribute disproportionately to the actual impact on populations. C3-MIOIP (2010b) reported similar information for the northwest region, identifying dugong specialists they termed "Key Informants" and experts that were skilled in hunting dugongs and regularly targeted them; these experts reported they killed between 10 and 200 dugongs in their lifetime. The fisher in Bevato that reported hunting over 50 dugongs in his lifetime also reported that he knew of at least ten other fishers like him that targeted dugongs and thus were at least semi-specialist hunters. This heterogeneity among fishers in the probability of hunting dugong may actually introduce a negative bias in the estimation of numbers of dugong hunted in each village, since it is certain that some of these hunters were missed, particularly in the larger villages surveyed. Furthermore, for those large villages where only a small percentage of total fishers were interviewed, it far less likely that the sample of surveyed fishers is representative of the total fisher population. For this reason, and the non-systematic nature of the sampling, we suggest caution in extrapolating our sample results out to estimate the total dugongs hunted over time for any village or location. Even with this caveat acknowledged, it is certain that our reported data represent only a fraction of the total hunting and by-catch along the entire west coast, since we have surveyed only a small portion of the total west coast population of fishers, and only a portion of the fishers in each location visited.

The aerial survey study of Van Conneyste et al. (2010) is the only currently available work reporting recent documentation of live sightings of dugongs in Madagascar using a direct monitoring methodology. During surveys in December 2009, live dugongs were sighted on seven occasions; one was in the general Ampasindava region in the northwest, providing some supporting evidence for an extant population in this region reported from other sources (Cooke et al. 2003, Rosenbaum 2003, C3-MIOIP 2010b). The majority of sightings (six) occurred on an approximately 150km stretch of coast between Mahajanga and Sahamalaza (south of the Nosy Be region), an area that has not been surveyed in any manner by our or any of the previously cited studies. The most southerly two sightings of Van Conneyste et al. (2010) were approximately 30km and 50km north of Mahajanga, congruent with our finding of relatively recent reports of by-catch in the Mahajanga region. The Van Conneyste et al. (2010) aerial surveys also covered broad regions of the central west coast, including the Barren Islands, the southwest coast, including the Andavadoake region, and the northeast coast, including Antongil Bay and the Masoala peninsula, with no dugong sightings made in these regions. This is potentially in conflict with the data reported here for the Andavadoake region, and elsewhere for Masoala (Wildlife Conservation Society 2012). However, the aerial surveys of Van Conneyste et al. (2010) were extremely wide-reaching, covering both coastal and oceanic habitat extending hundreds of kilometers offshore to the oceanic islands surrounding Madagascar; thus the transect design was not optimized for a fine-scale assessment of coastal or shallow-water dugong habitat. It is possible that the aerial surveys did not pick up sightings in these other regions for that reason, and/or that the Mahajanga to Sahamalaza coast represents an area with significantly higher density and numbers of dugongs. It is also possible that seasonal movements of animals may account for the differences among the studies, since the aerial surveys represent a snapshot in time, whereas the interview reports conflate all seasons of the year.

From a conservation perspective, the interview results we report are alarming and suggest the need for prompt action. This existing data, along with other recent studies on the northwest (C3-MIOIP 2010b, Van Conneyste et al 2010) and northeast coasts (Wildlife Conservation Society 2012) of Madagascar can be used to establish priority areas for conservation actions. The ‘hotspot’ among the locations covered in our survey appears to be in the southwest, in the general Andavadoake region, due to the most recent reports of dugong presence and hunting pressure. However, there is evidence for other locations in our survey, in particular the Barren Islands and Nosy Mitsio, to have historical importance, and relatively recent (1990s and early 2000s) reports of live sightings and hunting pressure. Also, there are several regions not covered in this study that represent other areas where there are recent reports of sightings or capture, such as the northwest coast from Irohana to Vohilava including notably Ampasindava and Nosy Hara (C3-MIOIP 2010b), the coast north of Mahajanga to Sahamalaza (Van Conneyste et al 2010), and Antongil Bay (Wildlife Conservation Society 2012). Some of these areas may represent areas of higher sighting frequency than in our surveyed areas, but it is difficult to ascertain from the existing information.

RECOMMENDATIONS

Most importantly, our data present evidence for a very recent and rapid decline in reports of dugongs, suggesting ongoing hunting and by-catch pressure. It is highly likely that the current rate of removal of dugongs is unsustainable and contributing to the contraction of the range, fragmentation of the population, and ultimately leading to extirpation of the population in parts of, or the entirety of its range. Further work is recommended, both in the form of extended interview surveys to expand geographic coverage and fill gaps, and other monitoring methods such as aerial surveys to directly assess the distribution and density of dugong populations in Madagascar. Given the encouraging results of Van Conneyste et al. (2010), it is recommended that well designed fine-scale aerial surveys focusing on coastal and shallow-water habitat be conducted throughout the year in all regions that have been identified as potentially important dugong areas. Critically, active conservation work should commence in the key areas identified in this and other studies, irrespective of the advancement of further survey and monitoring work (i.e., it should not wait until more results are available or published). Conservation measures should be

aimed at local education and awareness raising, and mitigation of by-catch and hunting through establishment of community-managed protected areas and local legal mechanisms such as establishment of “dina”, the traditional Malagasy governance system (Rokatoson & Tanner 2006, Andriamalala & Gardner 2010). Of some encouragement, in the past 10 years there has been an effort to increase the number of Marine Protected Areas in Madagascar (Harris 2011). As a result, MPAs have been, or are in the process of being implemented in several of the areas identified as currently or historically important to dugongs along the Madagascar west coast. These include, from north to south, Ampasindava (Nosy Hara MPA, fully gazetted), Nosy Mitsio (Ankarea MPA, provisional protection status), Sahamalaza (Sahamalaza Iles Radama MPA, fully gazetted), the Barren Islands (assessment in process, no protection status yet), and the Andavadoake region (Velondriake MPA, provisional protection status). The only identified dugong hot spot area along the west coast with no MPA is the coast north of Mahajanga to Sahamalaza. Efforts should be made to strengthen and support the existing MPAs, develop new ones where needed, and give careful consideration to linking the protected areas in a network (Harris 2011) that considers the needs of dugong populations and what measures should be implemented to constitute effective dugong conservation.

ACKNOWLEDGEMENTS

This work was greatly facilitated by the staff of the Wildlife Conservation Society’s Marine Program (MP), Ocean Giants Program (OGP) and Madagascar Country Program (MCP). Howard Rosenbaum played a role in identifying and raising funding, and as director of the OGP. Sarah Pacyna, Lina Fan, Victoria Cordi and Grace Seo provided invaluable administrative support from the MP and OGP. The MCP provided programmatic and logistical support that ultimately makes work in Madagascar possible, and in particular we are grateful for the efforts of Lisa Gaylord, Christopher Holmes, Ambroise Brenier, Luccianie Raonison, Cesaire Ramilison, and Sylviane Raharivelo. The early stages of this work in the early/mid 2000s were facilitated by Yvette Razafindrakoto. During the 2010 long-range survey we were greatly assisted by Grant Ruffel, Gaston Bernal and the crew of the Zanj. Funding was provided by the Flora Family Foundation, the Eppley Foundation for Research, the IUCN’s Kate Sanderson Bequest, the International Whaling Commission’s Small Cetacean Research Fund, the John D. and Catherine T. MacArthur Foundation, and an anonymous donor.

LITERATURE CITED

- Andriamalala G and Gardner CJ. 2010. The use of *dina* as a natural resource governance tool; lessons learned from Velondriake, south-west Madagascar. *Trop. Conserv. Sci.* 3: 447-472
- Andrianarivelo N., 2001. Essai d’évaluation de l’importance de la pêche aux dauphins dans la région d’Anakao (sud-ouest de Madagascar). Unpublished DEA thesis. Institut Halieutique et des Sciences Marines, Université de Toliara, Madagascar.
- Cerchio S., Andrianarivelo N., Razafindrakoto Y., Mendez M., and Rosenbaum H. 2009. Coastal dolphins hunting in the southwest of Madagascar: status of populations, human impacts and conservation actions. Paper SC/61/SM15 presented to the International Whaling Commission.
- Cockcroft V.G. 1993. A Preliminary Assessment of the Status of Madagascar Coastal Resources, with Special Reference to Marine Mammals and Reptiles. Final report for United Nations Environment Programme. South African Department of Foreign Affairs and African Wildlife. 16pp.
- Cockcroft V.G. and Young D.D. 1998 An Investigation of the Status of Coastal Marine Resources along the West Coast of Madagascar. Mission report to WWF, unpublished. 58pp

- Cooke A., Lutjeharms J.R.E., and Vasseur P. 2003. Marine and Coastal Ecosystems. In: Goodman, S. and Benstead, J. (eds) *Natural History of Madagascar*. Chicago University Press, Chicago, IL, p 179–209.
- C3 Madagascar and Indian Ocean Islands Programme (2010a) Study to Confirm the Existence or Extinction of Dugongs in the Waters of Mauritius. A Report Submitted to the Convention On Migratory Species Of Wild Animals (CMS) Secretariat, Abu Dhabi. 12pp
- C3 Madagascar and Indian Ocean Islands Programme (2010b) Rapid Assessment of Dugongs and their Seagrass Habitat in Northern Madagascar. A Report Submitted to the Convention On Migratory Species Of Wild Animals (CMS) Secretariat, Abu Dhabi. C3 Technical Report Series No. 6. ISSN 1754-5188. Community Centred Conservation (C3), London, UK. 19pp.
- Gough C., Thomas T., Humber F., Harris A., Cripps G., and Peabody, S. 2009. Vezo Fishing: An Introduction to the Methods Used by Fishers in Andavadoaka Southwest Madagascar. Blue Ventures Conservation Report.
- Harris AR. 2011. Out of sight but no longer out of mind: a climate of change for marine conservation in Madagascar. *Madag. Conserv. & Develop.* 6: 7-14.
- Marsh H. 2008. Dugong dugon. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. www.iucnredlist.org
- Marsh H., Penrose H., Eros C., and Hugues J. 2002. Dugong Status Report and Action Plans for Countries and Territories. Report Series. Early Warning and Assessment , United Nations Environment Program UNEP/DEWA/RS.02-1.
- Razafindrakoto Y., Andrianarivelo N., Cerchio S., Rasoamananto I., Rosenbaum H.C. 2009. Preliminary assessment of cetacean incidental mortality in artisanal fisheries in Anakao, Southwestern region of Madagascar. *Western Indian Ocean J. Mar. Sci.* 7:175-184.
- Rokatoson LR, and Tanner K. 2006. Community-based governance of coastal zone and marine resources in Madagascar. *Ocean & Coastal Manag.* 49: 855-872.
- Rosenbaum H.C. 2003. Marine Mammals. In: Goodman, S. and Benstead, J. (eds) *Natural History of Madagascar*. Chicago University Press, Chicago, IL, p 213–216.
- Van Canneyt, O., Dorémus, G., Laran, S., Ridoux V., Watremez, P. 2010. Distribution et abondance de la mégafaune marine dans le sud sud-ouest de l’océan Indien tropical. Campagne REMMOA - Océan Indien - Rapport préliminaire. Université La Rochelle.
- Wildlife Conservation Society 2012. UNEP/CMS Dugong Questionnaire Report for Antongil Bay, Madagascar. Unpublished report submitted to the Convention On Migratory Species of Wild Animals (CMS) Secretariat, Abu Dhabi.
- WWF Eastern African Marine Ecoregion. 2004. Towards a Western Indian Ocean Dugong Conservation Strategy: The status of Dugongs in the Western Indian Ocean Region and Priority Conservation Actions. Dar es Salaam, Tanzania: WWF. 68pp.

TABLES AND FIGURES

Table 1. Description of locations that were sampled and the interviews that were conducted. “Villages” indicates the number of separate villages that were visited at each location; the estimated population (“Est Pop”) and estimated number and percentage of fishers living in the villages (“Est #Fishers” and “%Pop Fishers”) are the summations for all indicated villages, as estimated by an elder or mayor in each village. Interviews are defined as each separate interview session (“Tot #Interv”) irrespective of number of individuals; “Single Interv” indicate number of sessions with a single person, and “Focus Grps” indicate the number of sessions that were focus groups of 2 or more people; “Tot Individ” is the summation of all people present in all sessions, and “%Fisher Interv” is the percentage of the estimated number of fishers represented by “Tot Individ”.

Location	Location Stats				Interview Stats				
	Villages	Est Pop	Est # Fishers	%Pop Fishers	Tot #Interv	Single Interv	Focus Grps	Tot Individ	%Fisher Interv
Nosy Mitsio	18	547	142	26%	41	31	10	57	40%
Nosy-Be	8	14170	656	5%	24	14	10	140	21%
Nosy Faly/GT	5	2979	1055	35%	12	2	10	137	13%
Mahajanga	4	2300	1390	60%	13	4	9	27	2%
Barren Islands	3	60	60	100%	5	0	5	20	33%
Ambozaka	1	2040	1800	88%	3	0	3	12	1%
Morondava	2	8980	1700	19%	4	0	4	13	1%
Belo sur mer	3	5187	3440	66%	30	17	13	107	3%
Morombe	2	9144	2220	24%	6	1	5	20	1%
Bevato	1	437	300	69%	9	3	6	37	12%
Andavadoake	4	1392	668	48%	27	13	14	56	8%
Bevohitse	3	475	251	53%	24	14	10	57	23%
Ifaty	4	11540	3730	32%	12	7	5	29	1%
Totals	58				210	106	104	712	

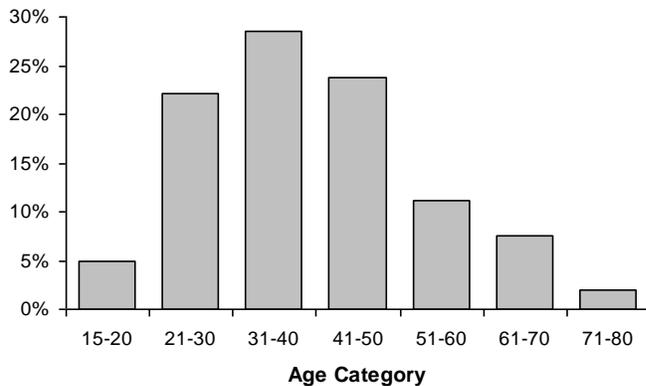


Figure 1. Age composition of all individuals interviewed in all villages.

Table 2. Summation of all reports of dugongs in all interviews for each location, irrespective of time period being reported (ranging from 1950-2010). Values represent actual numbers of individual dugongs reported, and are grouped by whether they were hunted, by-caught, stranded or sighted live.

Location	Hunt	By-catch	Stranded	Live	Total
Nosy Mitsio	0	53	3	5	61
Nosy-Be	0	0	0	0	0
Nosy Faly/GT	1	3	0	0	4
Mahajanga	0	10	0	5	15
Barren Islands	101	0	0	3	104
Ambozaka	0	0	0	2	2
Morondava	0	0	0	0	0
Belo sur mer	8	5	0	1	14
Morombe	0	0	0	0	0
Bevato	166	11	0	25	202
Andavadoake	34	10	0	69	113
Bevohitse	8	9	1	0	18
Ifaty	0	0	0	0	0
All locations	318	101	4	110	533

Table 3. Summation of recent reports of dugongs for each location, for years 2000-2004 and 2005-2010. Values represent actual numbers of individual dugongs reported, and are grouped by whether they were hunted, by-caught, stranded or sighted live.

Location	2000-2004				2005-2010			
	Hunt	By-catch	Strand	Live	Hunt	By-catch	Strand	Live
Nosy Mitsio	0	2	0	1	0	0	0	0
Nosy-Be	0	0	0	0	0	0	0	0
Nosy Faly/GT	0	0	0	0	0	0	0	0
Mahajanga	0	4	0	0	0	2	0	0
Barren Islands	1	0	0	2	0	0	0	0
Ambozaka	0	0	0	0	0	0	0	0
Morondava	0	0	0	0	0	0	0	0
Belo sur mer	0	0	0	1	0	0	0	0
Morombe	0	0	0	0	0	0	0	0
Bevato	18	0	0	2	4	2	0	7
Andavadoake	9	6	0	4	6	1	0	2
Bevohitse	3	1	0	0	1	2	0	0
Ifaty	0	0	0	0	0	0	0	0
All locations	31	13	0	10	11	7	0	9

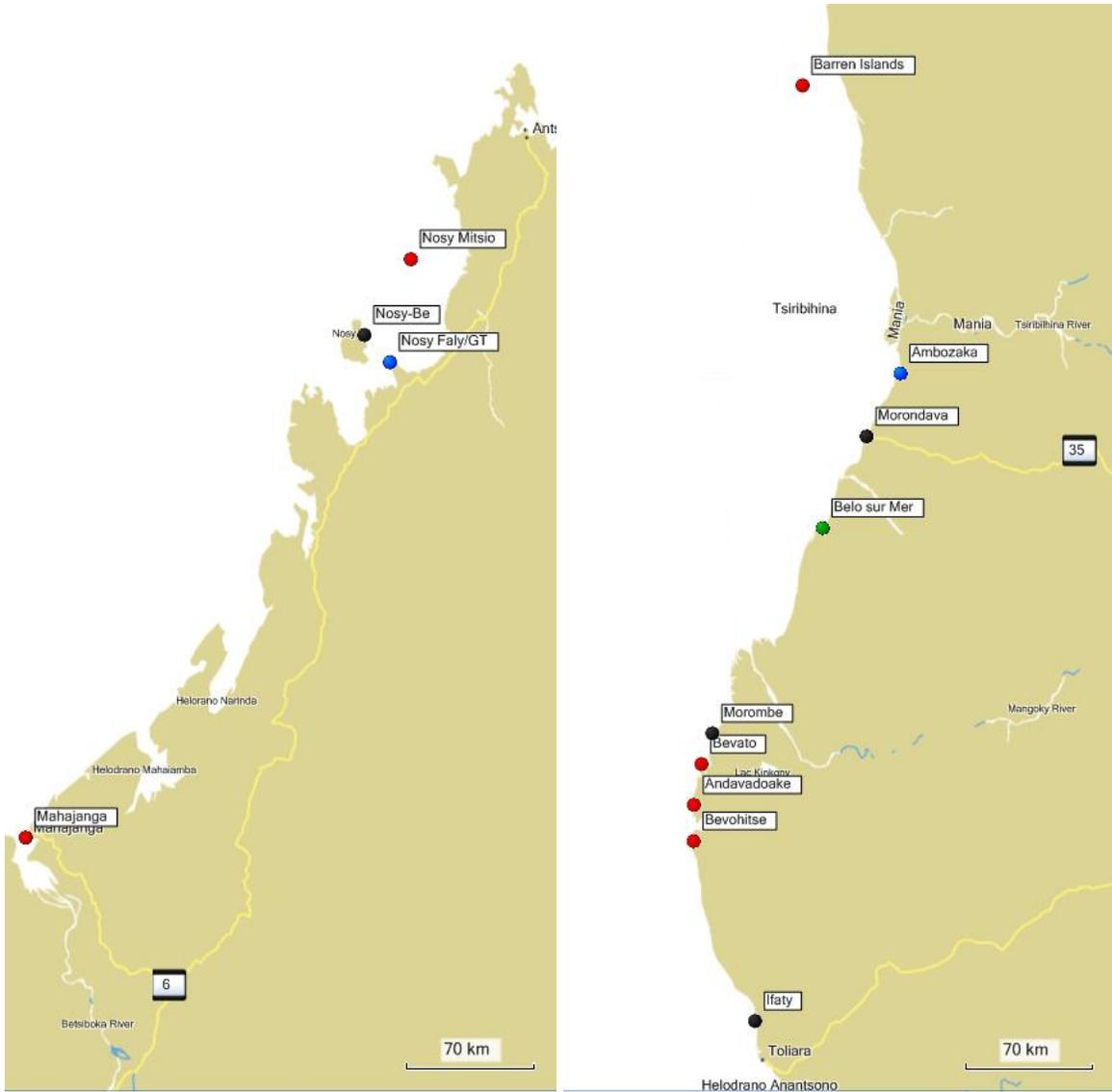


Figure 2. Position of locations where interviews were conducted in the northwest (left panel) and southwest (right panel) of Madagascar. Marker color indicates whether Dugongs were either hunted or by-caught during 2000-2010 (red), sighted live but not caught during 2000-2010 (green), reported only prior to 2000 (blue), or not reported at all (black).

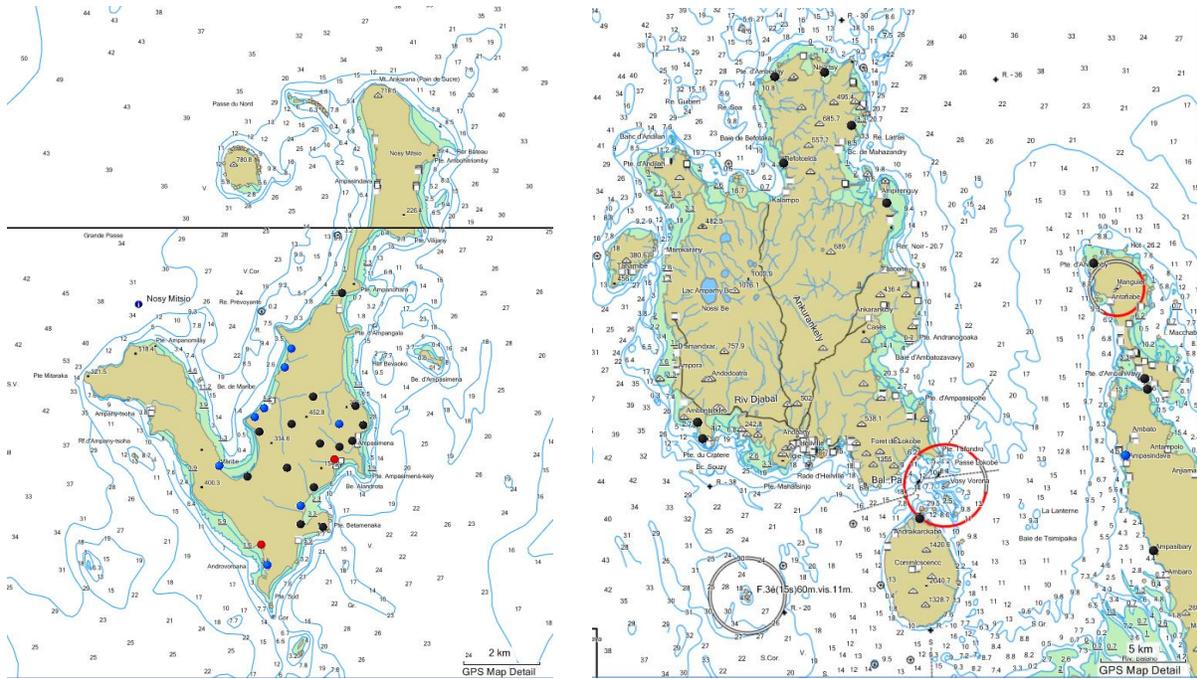


Figure 3. Details of villages where interviews were conducted in locations Nosy Mitsio (left panel) and Nosy Be and Nosy Faly/Grande Terre (right panel). Marker color indicates whether Dugongs were either hunted or by-caught during 2000-2010 (red), sighted live but not caught during 2000-2010 (green), reported only prior to 2000 (blue), or not reported at all (black).

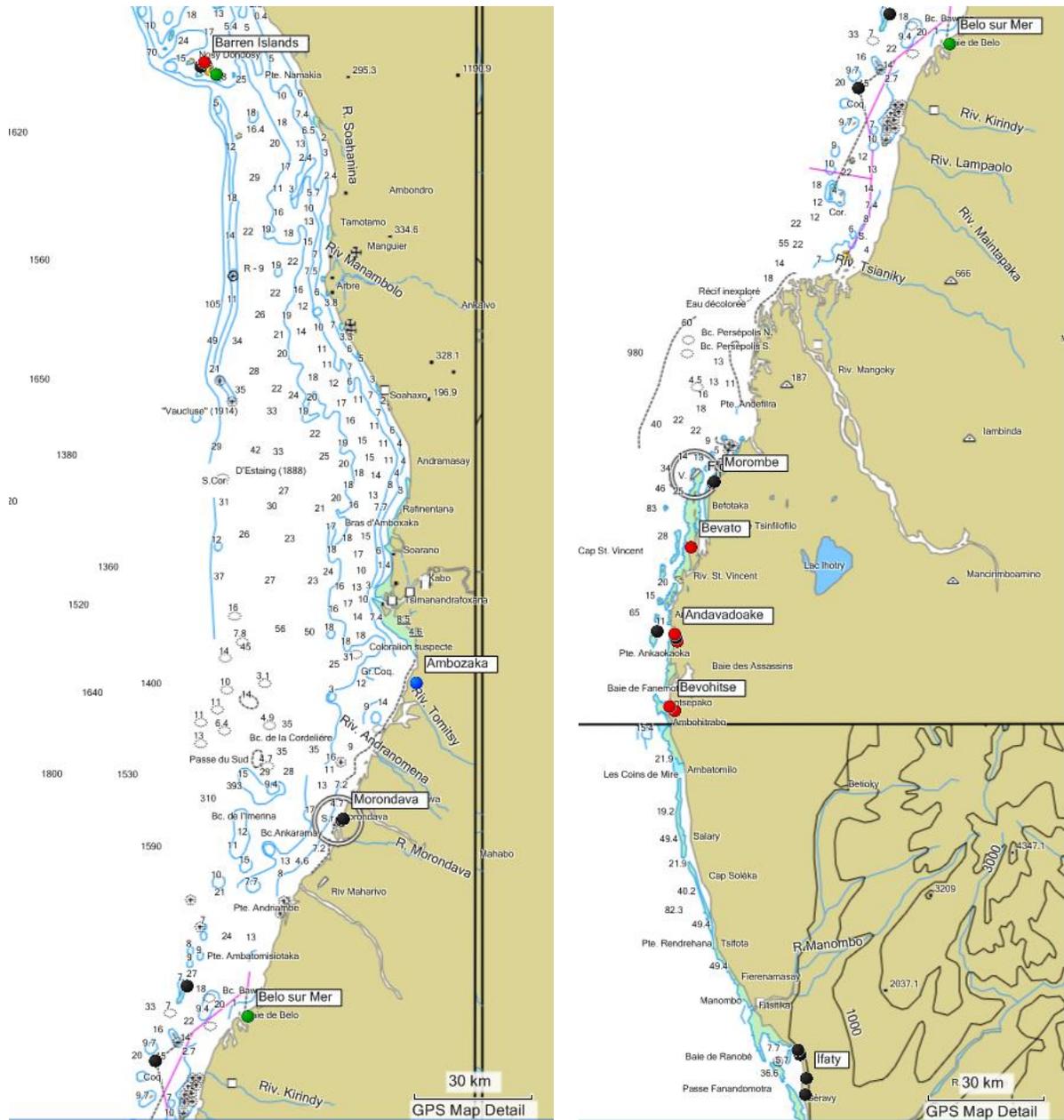


Figure 4. Details of villages where interviews were conducted in locations Barren Islands, Ambozaka, Morondava and Belo sur Mer (Left panel) and Morombe, Bevato, Andavadoake, Bevohitse and Ifaty (right panel). Marker color indicates whether Dugongs were either hunted or by-caught during 2000-2010 (red), sighted live but not caught during 2000-2010 (green), reported only prior to 2000 (blue), or not reported at all (black).

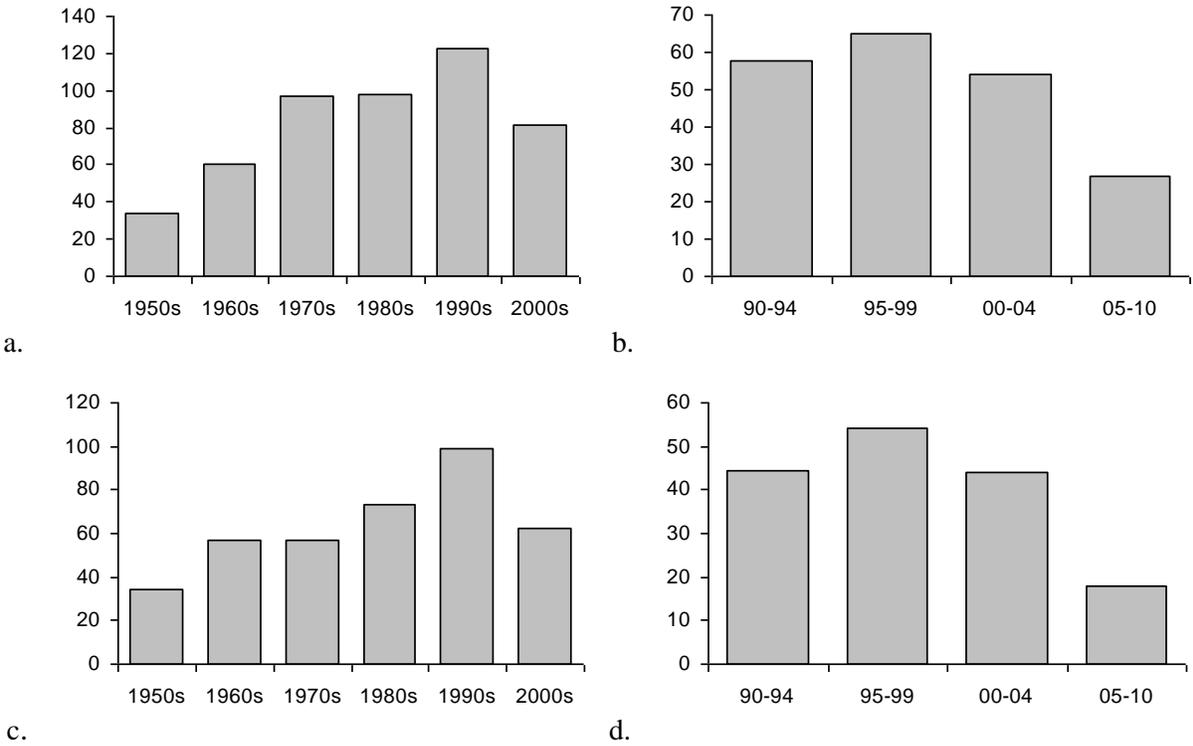
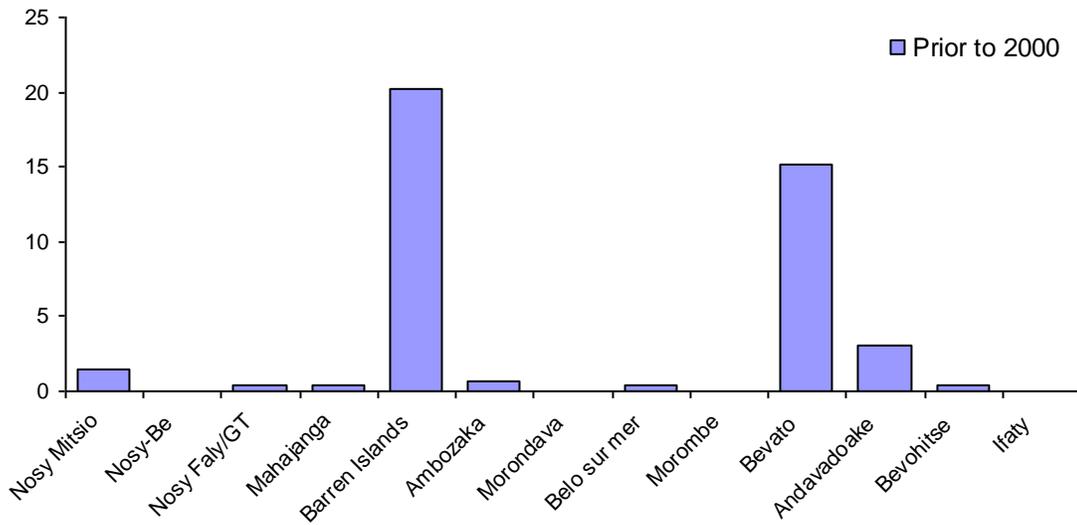
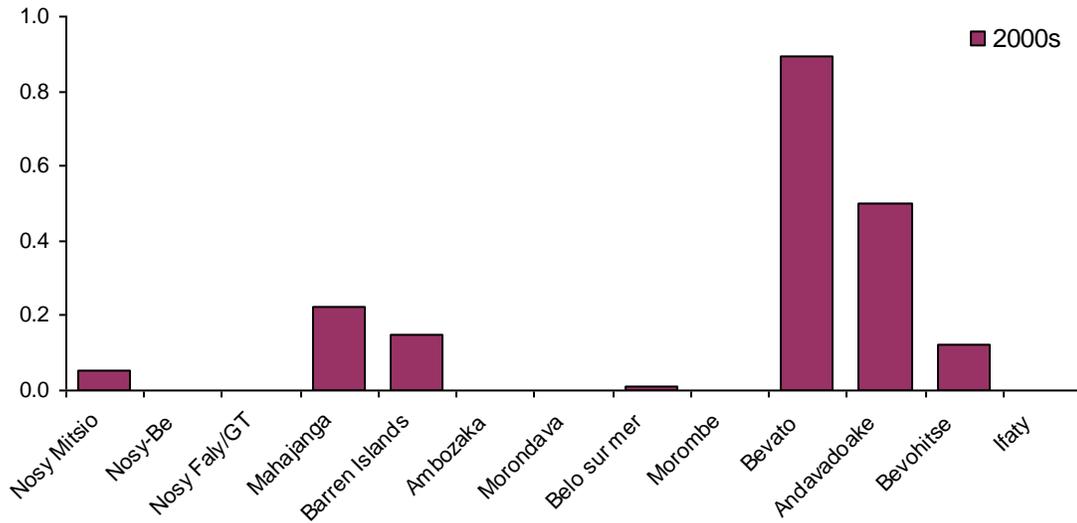


Figure 5. Temporal trend data, for all locations combined, in terms of: total reports of dugongs (hunted, by-caught, stranded and live sighting) by (a) decades, and for (b) 1990 to 2010 in 5 year blocks; and in total dugongs reported hunted or by-caught by (c) decades and for (d) 1990 to 2010 in 5 year blocks.



a.



b.

Figure 6. Regional comparison showing for each location the rate of dugong reports (summed number of dugongs reported / total number of individuals interviewed) for reports in all categories from (a) all years prior to 2000 and (b) the period from 2000 to 2010. Note the absolute rate is relative to the number of years being reported, so not directly comparable between the two periods, but comparison of the two periods reveals differences in the trends of where dugongs are primarily being sighted and caught among regions.

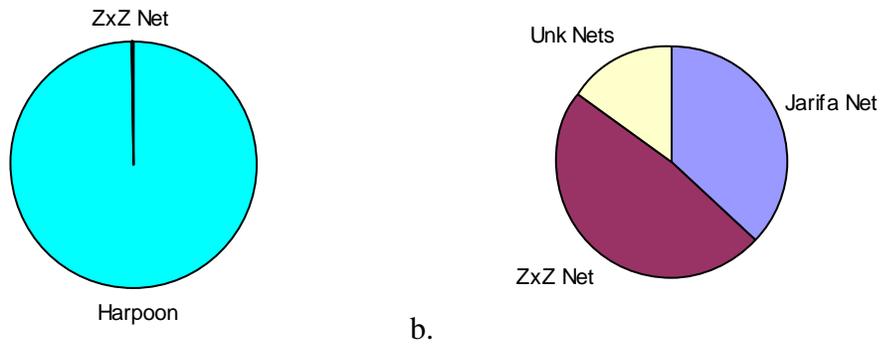


Figure 7. Fishing gear reported used during (a) hunting, where 99.6% of captures were made using harpoons, and (b) by-catch, where 48% of captures were made with “ZxZ”, a large mesh (8-10 cm) gillnet, and 37% of captures were made with “Jarifa”, a very large mesh (12-25 cm) gillnet, both used primarily for large pelagic fish and shark.