

# *The New Natural History of Madagascar*

Steve M. Goodman, Editor (in press)

## **Chapter 7 – Marine and Coastal Ecosystems**

Andrew Cooke, Subject Editor

### *Dugong dugon, Dugong, lambohara*

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## *Dugong dugon*, **Dugong**, *lambohara*

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### **Introduction**

The dugong (*Dugong dugon*) is the only living representative of its family Dugongidae, and one of four extant species within the order Sirenia, the other three being manatees within the separate family Trichechidae. Dugongs are strictly marine, feed on seagrasses, and are found in the Indo-Pacific, between east Africa and Vanuatu. Sirenians emerged in the middle Eocene about 50 million years ago (Domning and Gingerich 1994) and share common ancestors with the elephants (Proboscidea), hyraxes (Hyracoidea), and the extinct and hippo-like Desmostylans. Molecular genetic studies have consistently shown that sirenians share a common ancestry with a clade of African mammals, the Afrotheria, which include the elephants, hyraxes, aardvarks, elephant shrews, golden moles, and the tenrecs (Murata et al. 2003). A previously undescribed primitive dugong named as *Eotheroides lambondrano* sp. nov. (Sirenia: Dugongidae) has recently been described from middle Eocene deposits at Ampazony in northwest Madagascar, confirming the presence of ancestral dugongs in Malagasy coastal waters prior to the emergence of modern dugongs (Samonds et al. 2009).

### **Status**

Two decades ago it was already apparent that *D. dugon* was in critical need of conservation intervention (UNEP 2002), particularly in the western Indian Ocean (WWF-EAME 2004). In the absence of anthropogenic impacts, this coastal marine mammal has a low maximum rate of population increase of only 5% per year (Boyd et al 1999); hence, any additional mortality through hunting or accidental capture in nets can tip a small population into precipitous decline. Populations in the Indo-Pacific, particularly around islands, have suffered from overexploitation primarily due to direct and accidental capture (UNEP 2002) and local extinctions in the western Indian Ocean region have been recorded from La Réunion, Mauritius, and Rodrigues (C3 Madagascar and Indian Ocean Islands Programme 2010a). The use of gill nets is considered a major cause of mortality in the South West Indian Ocean, including Madagascar (Kizska et al. 2008).

The IUCN Red List considers the dugong's status as Vulnerable on a global scale (Marsh and Sobotzick 2019) with an estimated population decline of 20% in the last century (Marsh et al. 2002). However, this classification is based on a global average which includes significant populations in Australia (c. 85,000 individuals) (CITES 2000) and the Arabian Gulf (5800 individuals) (Preen 2004). In the western Indian Ocean *D. dugon* would be more appropriately classified as Critically Endangered, based on the fact that: 1) the largest population in the region is considered to be in Mozambique (200-300 individuals, Findlay et al. 2011) with only small fragmented and declining populations scattered across the coastlines of east Africa, Madagascar, Comoros, and the Seychelles and 2) the recent mitochondrial DNA analyses reveal that the Malagasy and Comorian populations are genetically distinct from the east African population (Plon et al. 2019).

A century ago, along with other now-endangered marine megafauna such as the sawfish *Pristis pristis* (Moriceau 1902; see Leeney, p. xx), dugongs were common and present in herds and large groups around Madagascar's vast coastline (Petit 1927). However, over the past half century they have suffered a precipitous decline, with sightings now very rare and usually of lone individuals or mother and calf pairs. The absence of encounters with this elusive marine mammal is reflected in the associated loss of traditional ecological

knowledge (stories, customs, and terminology) in the younger generation of fishers (Iyengar 2018).



Fig. 1: Dugong feeding on seagrass (credit : Laura Dinraths)

## Distribution

The distribution of *D. dugon* is determined by the occurrence of its sole food source, seagrass meadows (Marsh et al. 2002), which it shares in common with the green turtle *Chelonia mydas* (see Walker et al., p. xx). Prediction of its distribution in Madagascar waters has been hampered by the lack of systematic data on the distribution of seagrass beds (see Cooke et al., p. xx). However, with the realization of several seagrass surveys over the past decade, a clearer picture is emerging of the distribution of this habitat, which is generally associated with coral reefs.

The extreme northern region of Madagascar is notably one of the last areas where dugongs have continued to be observed in recent years by fishers, albeit infrequently, between the Sahamalaza Peninsula in the west and Vohémar in the east. As recently as 2010 dugongs were also encountered and targeted by fishers in the southwest region around Andavadoake, as well as sighted by aerial surveys in the northwest stretch of coast between Mahajanga and Sahamalaza.

Historical sightings, both anecdotal and verified, from the early 20th century to the present, have been noted throughout the shallow coastal zones of the island, from south of Anakao in the southwest, along the entire west coast and around Cap d'Ambre in the far north to the Bay of Antongil in the northeast, and further down the east coast as far as Ile Sainte Marie and Foulpointe (Mahavelona). This is to be expected, since dugongs can be wide-ranging and are dependent on relatively shallow, protected coastline where seagrass grows in abundance.

## Historical and Cultural Context

### Local Vernacular names

In different regions of Madagascar, *D. dugon* is known as *lambohara* / *lamboara* (*lambo* = pig, *hara* = reef), *lambodriake* (*lambo* = pig, *riake* = sea) or *trozogno* / *trozo* (term used for large marine megafauna, including whales). Outside of the northwest, *trozona* is used exclusively for “whale”, so usage for *D. dugong* is considered regional to the northwest, where the Sakalava people have a *fady* (taboo) for eating pig, and therefore do not apply that term to an animal which they do eat. In some areas of the northwest seagrass is referred to as *ahitrozona*, *ahotrozona* or *ahitrozo*, meaning ‘grass of the dugong’. Blench (2008) demonstrates the possible Bantu origin in the various Malagasy dialects for dugong (*lembwara* meaning large fish or whale in Malay). Also the Malagasy name for the wild pig, *lambo*, reflects Austronesian names for bovine. Near Andavadoake in southwest Madagascar a vezo fishing village is named Lamboara, presumably after the dugong.

Table 1. Dialectal names, attestation, and interpretation of local names of *D. dugon* in Madagascar by region.

Location (Dialect)	Vernacular name	Comment
Throughout Madagascar	<i>Lambohara</i>	<i>lambo</i> = ‘pig’; <i>hara</i> = ‘reef’
Masoala and Ile Saint Marie (Betsimisaraka)	<i>Lambondrano, lamboaran</i>	<i>lambo</i> = ‘pig’; <i>rano</i> = ‘water’; <i>ndrano</i> = ‘of the water’
Extreme Northwest and Northwest (Sakalava)	<i>Trozogno, trozo</i>	Lit. ‘whale’
West and Southwest (Vezo)	<i>Lambodriake</i>	<i>lambo</i> = ‘pig’; <i>riake</i> = ‘sea’; <i>ndriake</i> = ‘of the sea’
Mayotte (Kiboshy)	<i>Lamboara</i>	Malay <i>lembwara</i> , ‘large fish, whale’

### Hunting and Exploitation in Madagascar

Dugongs in Madagascar were first described in French literature by early explorers

(e.g., Leguat 1708) and later by the colonial scientist Petit (1927), who describes in great detail the sanctity surrounding traditional hunting excursions, the slaughter, and burial of the animal, in the southwest and northwest regions of Madagascar. Accounts of deliberate hunting excursions and encounters with herds of dugongs persisted into the 1960s, which contrasts starkly with the situation only 30 years later when most young fishers in the extreme northwest had never even heard of the animal and capture occurred opportunistically or accidentally while out fishing (C3 Madagascar and Indian Ocean Islands Programme 2010b). Dedicated hunting trips were from this point likely to prove fruitless given the scarcity of this species.

Rich folklore, beliefs, and taboos defined Malagasy peoples' traditional interactions with dugongs (Petit 1927; Cunningham et. al., 2011) a product of the danger and difficulty in the hunt, the recognition of physical similarities between humans and dugongs, and the desire to appease both ancestors and the spirit of the deceased animal on slaughter and burial. In north Madagascar, members or descendants of the Anjoaty tribe, known as mystics, or alternatively, chief fishermen from the village, were the only people conferred the right to preside over ceremonial slaughter. Another clan traditionally associated with the hunting of dugong are the Kajemby of the Soalala region in the west, a sub-group of Sakalava people who specialize in fishing, hunting and collecting marine resources, including dugongs. (Durbin 1994). From all accounts gathered as part of a cultural study in 2018, from southwestern, northeastern, and northwestern portions of country, it was clear that in past times dugong hunting existed but was, on the whole, neither frequent nor indiscriminate (Iyengar 2018). Although it is worth noting that this is somewhat at odds with other interview survey work that reported fairly extensive hunting in the latter half of the 20<sup>th</sup> Century, described in detail below.

The organization Community Centered Conservation (C3) conducted open-ended interviews with elder fishers in 2009 and 2017 in coastal settlements from Nosy Be in the northwest to Vohémar in the northeast, which provided insight into ancient capture methods. Traditionally, dugongs were captured using the *valakira* method whereby bamboo-structures were set in the water to create a disturbance which caused dugongs to move out towards open water. The animal would then be pursued by boat until they became distressed and fatigued, which facilitated capture. A similar method was applied using a harpoon (*samandra*, *ranjo*, and *famono hosatra*), often equipped with a wooden float so that the speared dugong could be pursued and asphyxiated once fatigued. These methods were generally reported by interviewees as outdated, although a harpoon may still be kept on board for this purpose according to two informants.

According to the reports from informants, contemporary methods for intentional capture are conducted from a 6-8 m motorized dugout canoe (pirogue) using gill nets (*ragaridy jarifa*, *zedazeda*), typically with a mesh size 3-7 fingers, 3-7 m in height and anywhere from 100 to 900 m long, normally used to target large fish. These nets, now widespread in Madagascar, are also thought to be the primary cause of incidental captures of dugongs. Six men are required to capture a dugong, four to manipulate the net and two to manage the boat. This is also to ensure compliance with *fady*, or local taboo, which requires six men from different families to confirm that sexual intercourse has not taken place with the animal (a similar requirement in Mohéli, Union of Comoros). The dugong is encircled with the net and the fishers create noise to cause the animal to panic and become entangled in the net and asphyxiated. Similar techniques are reported for dolphin hunting in the southwest, both the shift from harpoons to mono-filament net, and the driving of pods of dolphins into gill nets (Andrianarivelo 2001, Cerchio et al. 2015).

The number of 'dugong experts' estimated for each community (defined here as fishers who had knowledge on how to hunt dugongs and had targeted them in the past) varied



greatly between sites. Informants in the village of Ramena in Antsiranana Bay reported the highest number of dugong experts, with almost all fishers in the village believed to have captured dugongs at some time (including incidental captures, not just deliberate hunting). At Ampasindava village, near Nosy Hara in the far northwest, estimates of between 10 and 50 dugong experts were recorded. In contrast, further south at Nosy Faly near Nosy Be, only four such experts were identified. Certain older informants claimed to have killed between 10 and 200 dugongs during their fishing career, with five of them capturing dugongs on normal fishing excursions and one (who claimed to have caught 200) targeting dugongs exclusively. Dugong hunting specialists were also encountered during interviews in the southwest in Bevato and Andavadoake, central west in the Barren Islands, and northwest in Ambaro Bay and Ampasindava Peninsula, with individuals reporting that they killed 25-150 individuals during periods ranging from 20 to 50 years (Cerchio et al. 2012) (Table 2).

The effort in the sense of time, skill and cost, involved in the capture of a dugong (hunting excursion, killing, and ceremonial slaughter) was significant. The complex series of ritualistic activities that preceded and followed a dugong capture indicate that there was deep respect both for the animal and the hunter. There is indication from key informants that this was an uncommon, not a regular event.

After independence of Madagascar from French colonial rule in 1960, a range of factors facilitated intensive hunting and by-catch of the dugong; lack of maritime law enforcement, advent of motorized craft, coastal population growth, erosion of traditional values and customs, and proliferation of monofilament gillnets. This period of technical change is correlated with a marked decline in dugong sightings based on interviews, from the 1980s onwards, reported in independent and therefore corroborative interview surveys in both the northwest and southwest regions. A remark from a 103-year old elder from Ambolobozokely, in the far north of Madagascar, was that the lack of respect of traditions has led to the disappearance of the dugong (C3 2018).

## **Research Studies**

### ***Aerial Surveys***

It is important to note that most recent information available on dugongs in the coastal waters of Madagascar (apart from a couple of photographed kills) is based on fisher interviews and anecdotal communications; the exception was during a marine mammal aerial survey of northern and western Madagascar in 2009, which resulted in rare direct observations (Van Canneyt et al. 2010). During these aerial surveys in December 2009, live dugongs were sighted on seven occasions; one was in the Ampasindava region of the northwest and within Nosy Hara Marine Park, supporting earlier anecdotal evidence for an extant population in this region (Cooke et al. 2003; Rosenbaum 2003; C3 Madagascar and Indian Ocean Islands Programme 2010b). Six sightings occurred on an approximately 150 km stretch of coast in the northwest between Mahajanga and Sahamalaza, a region that is otherwise data-poor, suggesting that this region may also support an extant population.

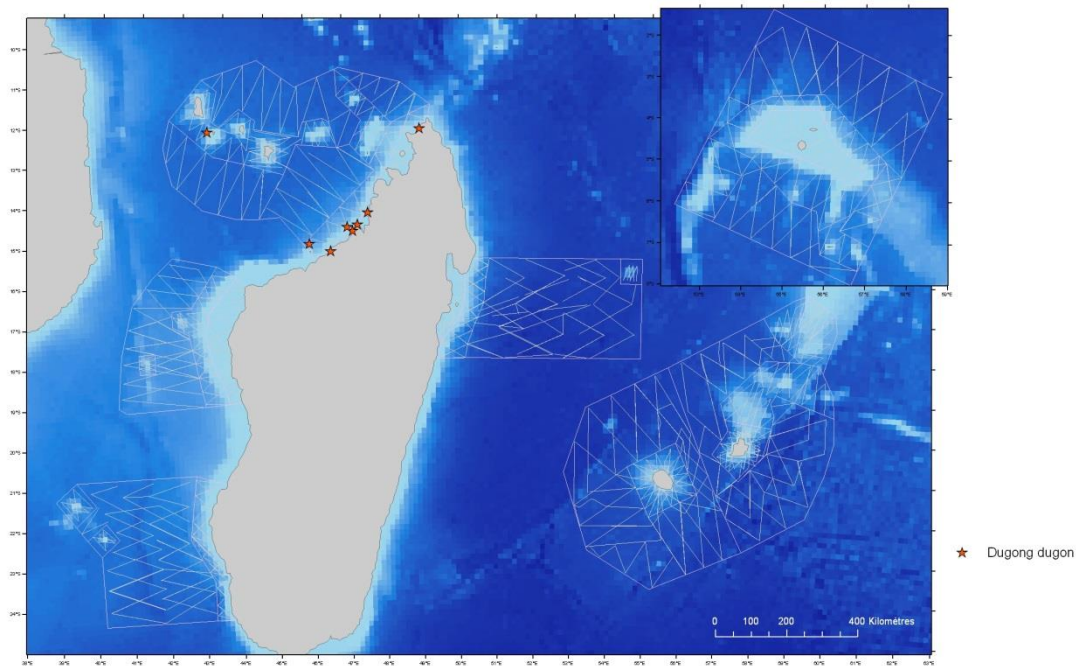


Fig. 2 Dugong sightings during 2009 aerial survey REMMOA Indian Ocean (Office français de la biodiversité- Observatoire Pelagis (CNRS- La Rochelle Université)

The Van Canneyt 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, but with no dugong sighting in these regions. However, it is important to note that the surveys were tailored for cetacean studies and therefore the transect design was not at a fine-scale assessment of coastal or shallow-water dugong habitat and is likely to have underestimated observations.

### *Interview Surveys*

**Extreme north:** A number of intensive interview surveys have been conducted with fishers since 2009 across northern Madagascar by various researchers, but it is not possible to compare data from these studies associated with methodological differences. In summary, the results confirm that dugongs still occur but are rarely encountered across the northwest and northeast coasts of Madagascar, based on observations of dead and live animals over the past 20 years. The main cause of death was accidental capture in gillnets, followed by deliberate opportunistic hunting.

C3's studies between 2009 and 2017, across the regions of Nosy Hara Marine Park, Ampobofobo, Bay of Rigny complex and Ambodivahibe, confirm the far north of Madagascar is still an important habitat for dugong, with mother and calf pairs sighted most consistently in the bays and around the islets of Nosy Hara Marine Park (C3 Madagascar and Indian Ocean Islands Programme 2010b).

The most recent dugong mortality was recorded in 2018 when a fisher opportunistically encountered and killed a dugong at Andovonkonko near the village of Ivovona in the Ambodivahibe region. The meat was sold in the village at 10,000 Malagasy Ariary (US\$2.80) per kilo. Samples of bone and tissue were collected and preserved for genetic analysis (C3 2018). Awareness of the existence of dugongs among fishers of less than 40 years old is almost non-existent (Iyengar 2018).

### **Relationship Between Dugong Occurrence and Seagrass Habitat**

As a complement to the interviews in the extreme north, C3 conducted surveys and ground-truthing of shallow seagrass habitats where *D. dugon* had been reported to occur (C3 Madagascar and Indian Ocean Islands Programme 2010b.). Spectral analysis of satellite imagery and examination of aerial photographs were employed to identify the potential location of seagrass habitats throughout the northern region of Madagascar from Nosy Be to Vohémar. Ground truthing at four sites where dugongs had been observed (Ampasindava, Andovonkonko, Antaravy, and Ramena) confirmed the presence of seagrass beds with high diversity (eight species) and variable densities (7.5%-38.6%) (see Cooke et al. p. xx).

Seagrass studies at localities where dugongs were sighted in Nosy Hara Marine Park revealed the presence of *Thalassia hemprichii*, *Cymodocea serrulata*, *Halodule uninervis*, *Halophila wrightii*, and *H. ovalis*, all of which are commonly consumed by dugongs. The seaward sites most preferred by dugong were characterized by seagrass communities dominated by *H. wrightii*, *H. uninervis*, and *C. serrulata* (C3 Madagascar and Indian Ocean Islands Programme 2010b).

The main threat to seagrass in this remote locality is potential wide scale destruction during cyclonic events, which occur on a near annual basis in the region. A study in 2013 in southwest Madagascar confirmed significant loss of seagrass after a cyclone (Côté-Laurin et al. 2017). Further, in eastern Australia, smothering by sediment and inundation from freshwater flooding associated with a cyclone led to large-scale die-off of seagrasses, followed by starvation and mortality of significant numbers of dugongs (Preen and Marsh 1995). However, food resource limitation is unlikely to impact the small remnant population of dugongs in Madagascar waters.

Species and density of seagrass beds at dugong hotspots with regular fisher observations post-2016 in Nosy Hara Marine Park are shown in Figure 3 (C3 2018). Anahibe was identified as a regular feeding area, with dugongs, including mother and calf pairs, observed 16 times over the two-year period. Other sites with between three and five sightings during the two-year period were Nosy Lonjo, Bobaloka, Lakantandiobe, Nosy Mahavony, and Ambatonankoay (C3 2018).

### **Northwest:**

Interviews were conducted at 20 villages adjacent to Sahamalaza Marine Park in 2015 (Razafindrakoto et al. 2018). Results revealed sightings as recent as 2015 of dugongs in Ambatolava (east of Nosy Berafia), Ankasetra (west of Nosy Valiha), and Ambatobe (in Sahamalaza Bay) including mother and calf pairs. Seagrass beds were estimated to cover approximately 6465 ha and feeding trails were recorded. However, as in other localities, the majority of sightings were from the 1990s or prior and most young people were unaware of the existence of dugongs.

### **West, Southwest, and Masoala Peninsula**

Socio-ecological interview surveys were conducted in villages on the west coast of Madagascar during several expeditions between 2008 and 2013, focused on marine mammals including dolphins, whales, and dugongs (Cerchio et al. 2012; S. Cerchio and N.



Andrianarivelo, unpublished data). Individual and group interview surveys were held with fishers, aimed at gathering traditional knowledge and information on hunting and by-catch of all marine mammals, and conducted in 78 villages in 15 locations from Nosy Mitsio and Ambaro Bay in the northwest to Ifaty in the southwest. During the same period and effort, interviews were also conducted at five villages around the Masoala Peninsula in the northeast (B. Andrianantenaina, unpublished data). Overall 1102 individuals were interviewed in 364 interview sessions (195 with individuals, and 169 with focus groups) (Table 2).

The interviews revealed accounts of hunting, by-catch, and sightings of live animals dating back to the 1950s and were grouped by decade to assess perceived trends in population status among the areas. Extensive hunting and by-catch was reported from in Ambaro Bay and Ampasindava Peninsula (including Ankivonjy Marine Protected Area) in the northwest; the Barren Islands in the central west; and Bevato in the southwest. Hunting was also reported to a somewhat lesser degree from Nosy Faly in the northwest; Belo-sur-Mer, Andavadoake, and Bevohitse in the southwest; and Masoala in the northeast. Bycatch (but no directed hunting) was reported from Nosy Mitsio and Mahajanga (northwest), and only live sightings were reported from a few interviews in the Ambozaka region (central west). No accounts were reported during interviews at Morombe, Morondava, or Nosy Be, although there are previous reports from at least the two former areas which had relatively little survey effort (Table 2).

Table 2. Accounts of dugongs reported during socio-ecological interview surveys from 2008-2013 at 15 locations along the west coast from Nosy Mitsio to Ifaty, and on the northeast coast at Masoala Peninsula (Cerchio et al. 2012). Sample size is presented as “number of interviews” / “total number individuals interviewed” since in many cases there were focus groups. Results are represented as number of individual dugongs reported for each time period in three categories: “Total Reported” / “Hunted” / “Bycaught”.

<b>Location</b>	<b>Interviews / Individuals</b>	<b>1950-1980</b>	<b>1980s</b>	<b>1990s</b>	<b>2000s</b>
Nosy Mitsio	41 / 58	8 / 0 / 8	18 / 0 / 18	32 / 0 / 25	3 / 0 / 2
Ambaro Bay	60 / 250	483 / 479 / 4	233 / 230 / 3	31 / 26 / 5	25 / 4 / 19
Nosy Faly	22 / 141	1 / 1 / 0	22 / 21 / 1	23 / 20 / 3	0 / 0 / 0
Nosy Be	24 / 143	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Ampasindava Peninsula	56 / 97	38 / 33 / 1	84 / 65 / 9	16 / 5 / 5	13 / 2 / 4
Mahajanga	13 / 27	4 / 0 / 0	1 / 0 / 0	1 / 0 / 1	6 / 0 / 6
Barren Islands	5 / 20	41 / 41 / 0	30 / 30 / 0	31 / 30 / 0	3 / 1 / 0
Ambozaka	4 / 13	2 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Morondava	4 / 12	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Belo-sur-Mer	30 / 107	6 / 5 / 0	6 / 1 / 4	4 / 3 / 1	1 / 0 / 0
<b>Morombe</b>	<b>7 / 21</b>	<b>0 / 0 / 0</b>	<b>0 / 0 / 0</b>	<b>0 / 0 / 0</b>	<b>0 / 0 / 0</b>
Bevato	9 / 15	89 / 80 / 1	59 / 52 / 3	21 / 12 / 5	33 / 22 / 2
Andavadoake	28 / 57	30 / 0 / 0	26 / 6 / 0	26 / 14 / 1	28 / 15 / 7
Bevohitse	24 / 79	1 / 1 / 0	4 / 3 / 1	6 / 0 / 5	7 / 4 / 3
Ifaty	12 / 29	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Masoala Peninsula	25 / 32	42 / 19 / 0	29 / 5 / 0	1 / 0 / 0	1 / 0 / 0
<b>Totals</b>	<b>364 / 1102</b>	<b>744 / 659 / 14</b>	<b>511 / 412 / 39</b>	<b>191 / 109 / 51</b>	<b>120 / 48 / 43</b>

Overall, reports pointed to a decimation in dugong populations in recent decades, especially during and after the 1980s and 1990s. In most areas the predominant reports were accounts prior to 2000, and some suggesting decline even between 2000 and 2010. In the northwest areas with the most accounts (Ampasindava Peninsula and Ambaro Bay) there was a precipitous decline in reports after 1990.

It should be noted that data from Ambaro Bay indicated a much higher occurrence of dugong accounts, particularly hunting, than any other region surveyed. It is possible that some of this is inflation due to a positive bias on the part of fishers to respond for some reason that is not understood; however, without any data on pre-exploitation abundance of dugongs in northwest Madagascar during the first half of the 20th century, it is also feasible that a healthy population could be large enough to withstand this reported level of exploitation over a few decades. In such a scenario, these interview results could reflect the depletion of a relatively large population of dugongs during the 1970s and 1980s, and population crash by the 1990s. Conversely, in the southwest “hotspot” (Andavadoake and Bevato) the number of reports was relatively constant from the 1980s through the 2000s. As for the other regions surveyed, there was evidence for possible near-extirpation (no reports since 2000 or 2005) around Nosy Mitsio, Nosy Faly, Belo sur-Mer, the Barren Islands, and Masoala (Table 2).

After 2005 dugongs were still being found and hunted in the northwest around the Ampasindava Peninsula and in Ambaro Bay, and in the southwest around Andavadoake, but not much elsewhere in the surveyed area. In most villages where hunting was prevalent, key individuals were responsible for the majority of kills. In Ambaro Bay, two separate fishers each reported killing at least 150 dugongs between 1960 and 1990, and 1965 and 1980, respectively, and a small focus group of two fishers reported hunting about three per year between 1950 and 1980, or approximately 120 dugongs; this represented 57% of all hunted dugongs in the surveyed Ambaro Bay villages. 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. In Andavadoake, a small focus group of two fishers reported hunting 25 dugongs from 1990 to 2009. In Bevato (a village in the Andavadoake area) a single fisher reported hunting at least 50 dugongs between 1954 and 1995. Conversely, reports of by-catch were more evenly distributed across interviewed fishers. Cerchio et al. (2012) concluded that this was likely evidence for dugong specialists as identified in other studies in the northwest (C3 Madagascar and Indian Ocean Islands Programme 2010b). In summary, recent high hunting pressure was reported only in Ambaro Bay and Ampasindava Peninsula/Ankivonjy MPA in the northwest, and Andavadoake (including Bevato) in the southwest. Previously important zones for dugongs appeared to include Nosy Mitsio, the Barren Islands, and the Masoala Peninsula.

### ***Historical Occurrence Records***

Over the last 20 years, one of the authors (AC) has maintained a record of miscellaneous reports of dugong sightings in Madagascar (Table 3). These records document sightings of 63 dugongs from the 1960s to the present, save one very early, outlier, observation from 1902 (Moriceau 1902). The records serve to illustrate the geographic range that dugongs have been observed over the last 50 or more years, while providing some additional contextual information and details. Such data complement the more targeted survey data summarized above and have been entered onto the distribution map (Figure 4) as points of historical occurrence. Perhaps of key importance is that the historical data highlight the northeast (Masoala and Ile Sainte Marie) for dugong, accounting for almost 50% of observations dating from 1973 to 2000 and no reports since 2000.

### **Genetic Studies**

Due to its threatened status and evolutionary distinctiveness, *D. dugon* is classed as an 'EDGE' (evolutionarily distinct and globally endangered) species with a very high ED index of 59.29, placing it as the sixth highest rated mammal globally and well above the median rating of 7.56 for all EDGE mammals (EDGE 2020). The dugong's extinction would therefore represent a disproportionately greater loss to global genetic biodiversity than the loss of most other mammal species.

Plon et al. (2019) investigated the phylogeography of *D. dugon* across its original range using museum material from 14 natural history museums. The mitochondrial DNA (mtDNA) control region was successfully amplified from samples of bone or tooth powder from 162 individuals collected between 1827 and 1996 and spanned the historical geographic range of the dugong. The resulting mtDNA sequences match those from previous studies of dugongs from Australia and Indonesia, but revealed several new and divergent mtDNA lineages in the Indian Ocean.

One mtDNA lineage includes most specimens from the western Indian Ocean, with another distinct lineage isolated to the waters of Madagascar and Comoros. There is little geographic structuring detectable among other populations in the western Indian Ocean and all appear to have historically contained comparatively low levels of genetic diversity, suggesting a certain level of inter-locality dispersal. The genetic diversity of several Indian Ocean samples collected after 1950 was lower than that of the samples collected earlier from similar locations, a result coincident with the anecdotal reductions in population size. The Madagascar and Comoros lineage is of particular conservation importance and highlights the vulnerability of dugong populations in this portion of the western Indian Ocean.

### **Legislation and policy**

Dugong hunting was banned originally by the French administration in the 1920s (Baker-Medard 2020) based on observations of hunting and concerns about the perceived decline in the population, a concern maintained by Petit (1930). Dugong were later integrally protected under ordinance 60-126 and its implementing decree 61-096. Dugong are listed in Annex I of CITES, Annex I of Convention on Migratory Species of Wild Animals (CMS), Annexes II and IV of the Nairobi Convention, and are listed as Class A species under the African Convention on the Conservation of Nature and Natural Resources (Algiers 1968), which Madagascar ratified in 1970 (law 70-004).

Dugongs enjoyed additional protection for a time under the fisheries law No. 93-022, article 9, which provided blanket protection for all marine mammals. However, since decree 61-096 was substituted by decree 2006-400, which does not list this species, and since law 93-022 was replaced with the new fisheries law 2015-053 which protects only species that are listed in existing regulations, dugongs (and other marine mammals) have technically fallen out of national legal protection. A government report of 2018 confirms the lack of specific protection for the dugong (MEEF 2018). This situation needs to be rectified without delay, for example by updating decree 2006-400 to include dugong (and other marine mammals).

Law enforcement will always be a considerable challenge across such a vast coastal region with poor infrastructure and limited government resources. In Madagascar waters, the future of the species depends very much on the behavior and decision-making of community members, particularly artisanal fishers, living in remote areas frequented by dugongs. Combined with awareness of its status and national laws, dugong protection can be incorporated into traditional resource management law or dina. This has been successfully achieved by C3 in the communities of Nosy Hara Marine Park and Rigny Bay. Such approaches have also been successful in dolphin conservation in the Anakao region south of Toliara, were a combination of community engagement, development of dina, and alternative

livelihood development has resulted in the cessation of organized dolphin hunting (Cerchio et al. 2015).

Through the United Nations Environmental Program's (UNEP) CMS, an international 'Memorandum for the Conservation of the Dugong and its Habitat' was established in 2007, to which Madagascar is a signatory. Although it is a non-binding agreement with voluntary participation, this instrument encourages all signatory range states to develop national conservation management plans for the species' future protection. By becoming the first signatory state of this MoU, Madagascar has shown its political commitment to conservation action for this threatened species, however a major weakness is the lack of legislation pertaining to the dugong and its critical habitat. A policy gap analysis was conducted by the Malagasy Government with regards to dugongs and seagrasses in 2018 as part of the UNEP GEF Dugong and Seagrass Conservation Project (Ratsimisaraka 2018). The report highlighted the gap in legal protection of the dugong described above, but also the absence of any policy for the protection of its seagrass habitat.

Ultimately, the promulgation and enforcement of specific legislation for the dugong will not alone be enough to prevent its extinction from Madagascar's waters. A national dugong conservation management plan needs to be developed and launched with a major focus on direct conservation and monitoring at community level. The plan must be appropriately geographically prioritized based on the best available information on dugong distribution in order to have the maximum chance for bringing the Madagascar dugong back from the brink of extinction with the limited resources available and starting to rebuild Madagascar's once important populations.

As part of the dugong conservation management plan, based on proven successes, conservation programs with investment at the village level, led by key community members in conjunction with NGOs and/or protected area managers such as Madagascar National Parks involved in co-management, in the localities where the dugong still persists, will be critical to the dugong's future survival in the decade to come.

### **Conservation Measures**

Results from all studies confirm that the dugong population in Madagascar waters which, together with the Comoros population, represents a unique genetic lineage, has been greatly depleted and is near extinction, based on comparison with historical anecdotal records and local knowledge. Dugongs appeared in herds in some regions of the northwest up until the 1960s. They were intensively exploited by coastal communities for their meat and oil, which increased with the introduction of motorized craft and accidental by-catch escalated with the introduction and proliferation of monofilament gillnets in artisanal fisheries. The development and expansion of industrial shrimp trawling along sections of the western and eastern coasts from 1967 and the expanding use of gill nets for shark fishing from the early 1990s may have introduced additional sources of mortality. Loss of seabed habitat due to high amounts of sedimentation may have further contributed to the decline of dugong populations.

The relative importance of different threats varies by region. In the extreme northwest the greatest threat is from incidental bycatch in gillnets, since organized dugong hunting is no longer viable following the decimation of the population (Temple et al. 2019; C3 Madagascar and Indian Ocean Islands Programme 2010b). Directed hunting may remain a serious threat in some areas of the northwest (Ambaro Bay and Ampasindava Peninsula) and southwest (Andavadoake area) where there are more recent reports of dugong (Cerchio et al. 2012; Cerchio and Andrianarivelo, unpublished data). Opportunistic capture based on chance encounter or by-catch using gill nets are sources of threat in all regions. It is important to emphasize that robustness of these conclusions is limited by interview effort, as many regions

have not been surveyed. There may be other areas (e.g., between Mahajanga and Sahamalaza identified by REMMOA aerial surveys) where there are persisting populations that may still be under continued hunting pressure. The potential threat of industrial trawling for shrimp or other species in shallow coastal waters has never been assessed and no data available.

Dedicated research and conservation efforts for dugongs in Madagascar waters only began in 2010. Prior to this, the focus of marine research and conservation campaigns has been on sustainable fisheries and cetaceans. Since 2010, C3 Madagascar has focused intense efforts on outreach to remote communities of Nosy Hara Marine Park, which includes incidental monitoring by members of the marine park committees (community representatives from 20 villages). Schools awareness campaigns and theatre and events are organized by the Junior Ecoguards youth network. The fact that mother-calf pairs are present in the park, especially around the small offshore islands, indicates the importance of the site for dugong conservation and the need to promote and maintain community involvement in monitoring and protection. Release from gillnets when entangled and absence of hunting is essential to the dugong's survival in this region.

In Sahamalaza Marine Park, where mother-calf pairs have also been sighted, awareness campaigns, ranger capacity building, and monitoring were initiated in 2016 under the GEF Dugong and Seagrass Conservation Project. Outreach campaigns have been regularly conducted with the production of communication materials on dugongs (signboards, posters, brochures, children's storybooks, and touring theatre) by C3 via its Junior Ecoguard Network, which is active in 100 schools from Nosy Be northwards and east to Rigny Bay. In addition, training in seagrass and dugong ecology, conservation, and monitoring has been offered to communities within national marine parks and Locally Managed Marine areas (LMMAs) across the far north (Rakotoarimino and Davis, 2017).

It is encouraging that areas of high priority for dugongs with recent live sightings are located within or near to national marine protected areas (Nosy Hara, Ankarea, Ankivonjy, Sahamalaza, Ambodivahibe, and Velondriake) and that LMMAs and regional fisheries management plans are also emerging in many areas important for dugong (see Cooke et al., p. xx). Furthermore, zones which were the focus of intense hunting in the recent past are also under protection (Andavadoaka LMMA established in 2004; Barren Isles LMMA established in 2004; Nosy Mitsio within Ankarea Marine Protected Area established in 2011). However, it is critical that management plans include specific actions for the protection and monitoring of seagrass and dugongs, as well as explicitly engaging and incentivizing fishers in these efforts, otherwise the conventional focus of marine protected areas on artisanal fisheries and coral reefs will fail to assure the dugongs' future survival. This concern is illustrated by the continued hunting of dolphins, as well as dugongs, in the Andavadoake region (Cerchio et al. 2015; see Cerchio et al. p. xx) despite the existence of the LMMA and marine protected area (Velondriake). Many of the communities in these areas live in extreme poverty, often earning less than 1 USD/day, and are under pressure to exploit all available resources to survive. Economic incentives will be needed to secure community support for conserving the dugong and its habitat in order to persuade fishers to end what is now primarily the opportunistic capture of dugong.

According to studies by Baker-Medard (2020), a history of colonial fisheries management policy based on European fisheries science, followed in most cases by similar top-down approaches to coastal resource conservation by international NGOs has left an indelible mark on fishers' perceptions of marine conservation intervention in certain areas of the island. This is exemplified by the killing of dugong and sale of its meat in 2018 by a fisher within the Ambodivahibe Locally Managed Marine Area (LMMA) despite the existence of the 'community-run' protected area since 2006 and associated conservation awareness building.



When fishers view conservation practices as another means of dispossessing them of their marine resources, exploitation of endangered species will continue to occur regardless of their awareness of laws and policies. The LMMA model is now due to be extended to encompass the entire Rigny Bay complex, another important remaining dugong habitat; it is essential that aside from implementing marine protected areas, international NGOs and other actors should ensure meaningful engagement with communities in the design of specific conservation and development actions at the field level. If not, communities will continue to feel dispossessed of their rights of access, will resent the messaging pushed by conservation organizations, and could deliberately hunt endangered species in order to assert their control over local resources.

Across the dugong's remaining range, awareness raising is still the most urgent and critical primary action that can be taken to help conserve the species, since most fishers, especially those under 40 years of age, are in fact unaware of the existence of dugongs, their role in the ecosystem or that they are highly endangered or protected by law. Without greater awareness, fishers are still likely to take dugongs they come into contact with.

In most areas where initial interviews have been conducted in the far north and north west, less than 10% of respondents were aware that the dugong even exists, let alone that it is highly endangered or protected by law (C3 Madagascar and Indian Ocean Islands Programme 2010b). With a rapidly expanding young population, education about the species should target children from primary age and be integrated into marine biodiversity within the school syllabus as well as included in wider environmental awareness campaigns. Women (and women's associations) should be actively targeted in incentivized conservation schemes that concern dugong protection; they have proven to be extremely motivated to learn about the status of their natural resources and take an active role in educating the wider community in sustainable use. Their main concern is the daily provision of food for the family, and they are often the most successful entrepreneurs, once given access to credit, in diversifying and/or increasing their household income.

Knowledge and respect for traditional customs and taboos should also be revived in conservation programs with engagement of key elders in their design and delivery, since many elders attribute loss of respect and understanding of traditions as a contributing factor to the species' decline. The successful outreach and engagement of fishers, women, and youth in dugong and seagrass monitoring and protection at Nosy Hara Marine Park and Sahamalaza Marine Park, integrated with an incentives scheme (e.g., provision of community services such as healthcare) proves that communities can be motivated to protect this rare species across its vast range. The dugong's prior importance in Malagasy culture and tradition should be emphasized, particularly with the engagement of elders and youth together, in the wider context of sustainable fisheries management and habitat restoration and protection.

Subject editor: Steven M. Goodman

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Table 3. Historical dugong observations up to 2003 (various sources).

Region	Location	Year	No.	Event	Remarks	Source
<b>NORTH</b>						
<b>Extreme northeast</b>	5 km SE of Antsiranana in Diego Bay	1975	1	Seen from boat	February 1975	D. Halleux, unpublished data
	Northern part of Diego Bay	1976	1	Seen from boat	December 1976	D. Halleux, unpublished data
	Andokovonko	2000	1	Accidental capture	Presence confirmed in Antsiranana region but rare	Maharavo et al. (2011)
<b>Northeast (Masoala Peninsula)</b>	Ambohimahery	1973	1	Captured	-	Rakotonirina (1999)
	Cap Masoala	1980	1	Seen by fishers	Fishers hunting with harpoon	D. Halleux (to M. Nicoll), unpublished data
	Ratsianarana	1980	2	Captured	-	Rakotonirina 1999
		1997	3	Seen	2 adults; 1 juvenile	Rakotonirina (1999)
	Ambodilaitry	1988	6	Captured	Single hunt	Rakotonirina (1999)
		1964-1998	3	Captured	Additional to 1988 captures	Rakotonirina (1999)
	Ambohombato	1995	1	Seen by fishermen	-	Rakotonirina (1999)
	Ratsianarana	1994	2	Seen by fishermen	Adults	Odendaal et al. (1995)
	Cap Masoala	1994	1	Seen by fishermen	Adult	G. van Schalkwyck, unpublished data
	Cap Est	1994	2	Seen by hotelier	Adults	
	Vinanivao	1997	1	Captured by fisher	Adult	Jaomanana and Rakotoarinivo, unpublished data
	Vinanivao	1997	1	Seen from air	January 1997	M. Hatchwell, unpublished data
	Antalaha	1998	3	Seen from air	October 1998	
	<b>Bay of Antongil</b>	<b>2000</b>	<b>2</b>	Seen by fishers	Nandrasana / Voloina	P. Doukakis and M. Jonahson, unpublished data
	Mananara (N)	2000	1	Captured	-	
<b>Extreme northwest</b>	<b>Ampasindava</b>	<b>2000</b>	<b>1</b>	Captured	One skull retained	B. Rakotonirina and R. Ratsimbazafy, unpublished data
	<b>Ampasindava</b>	<b>2000</b>	<b>3</b>	Seen by fishermen	August 2000	Metcalf et al. (2001)
	Ramena	2003	1	Butchered	Photographed	WWF-EAME (2004)



	Nosy Hara	2003	1	Caught	August 2003 photographed by Lyn Robinson	WWF-EAME (2004); Cooke and Brand (2012)
<b>Northwest</b>	Anjeba, Mahajamba	1902	1	Caught	Photographed male	Moriceau (1902)
	Soalala (Anky)	1990	1	Captured	Village of Anky "have been rare for 20 years"	Durbin (1991, 1994)
	Soalala (Antranolava)	1991	1	Captured with harpoons	Pregnant female First for 10 years – "have been rare for 30 years"	Durbin (1991, 1994)
	Mahajanga	1991	1	Captured	"In the Mahajanga region"	Cockcroft (1993)
	Analava	1993	1	Captured	-	G. Gaultier, unpublished data
<b>Central west</b>	<b>Morondava</b>	<b>1988</b>	<b>1</b>	Captured	Last known for Morondava	Rakotonirina (1999)
	Belo-sur-Mer	1999	>1	Several seen by fishermen	Occasional sightings	Rakotonirina (1999)
<b>Southwest</b>	Saint Augustin Bay	1990	1	Seen from yacht	-	Yacht skipper (pers. comm.)
	Morombe	1992	6	Captured	Caught by fishers; also reports no records between Toliara and Morombe	Cockcroft (1993)
	Morombe	1993	3	Captured	2 adults; 1 juvenile	Cooke and COUT (1994)
	Village south of Anakao	1996	1	Captured	Tail seen	G. Gaultier, unpublished data
	Salary north of Toliara	2000	1	Captured	Remains seen	G. Gaultier, unpublished data
<b>EAST</b>						
Ile Sainte Marie	Digue près de la 'capitale'	1982	1	Regularly seen	Injured, came regularly	D. Halleux, unpublished data
	Ile aux Nattes pass	1995	1	Seen from boat	1995	Fifou, CETAMADA, unpublished data
	Pointe de l'Ile aux Nattes	1997	1	Seen from boat	1997	Fifou, CETAMADA, unpublished data
	Vohilava, southwest coast of Ile Sainte Marie	1998	1	In a fisher's net	1998	H. Bellon CETAMADA, unpublished data
	Foulpointe	1982	1	Harpooned by cooperant	Regularly seen, tame, near beach	D. Halleux, unpublished data
<b>TOTAL</b>		<b>102 years</b>	<b>&gt;63</b>			

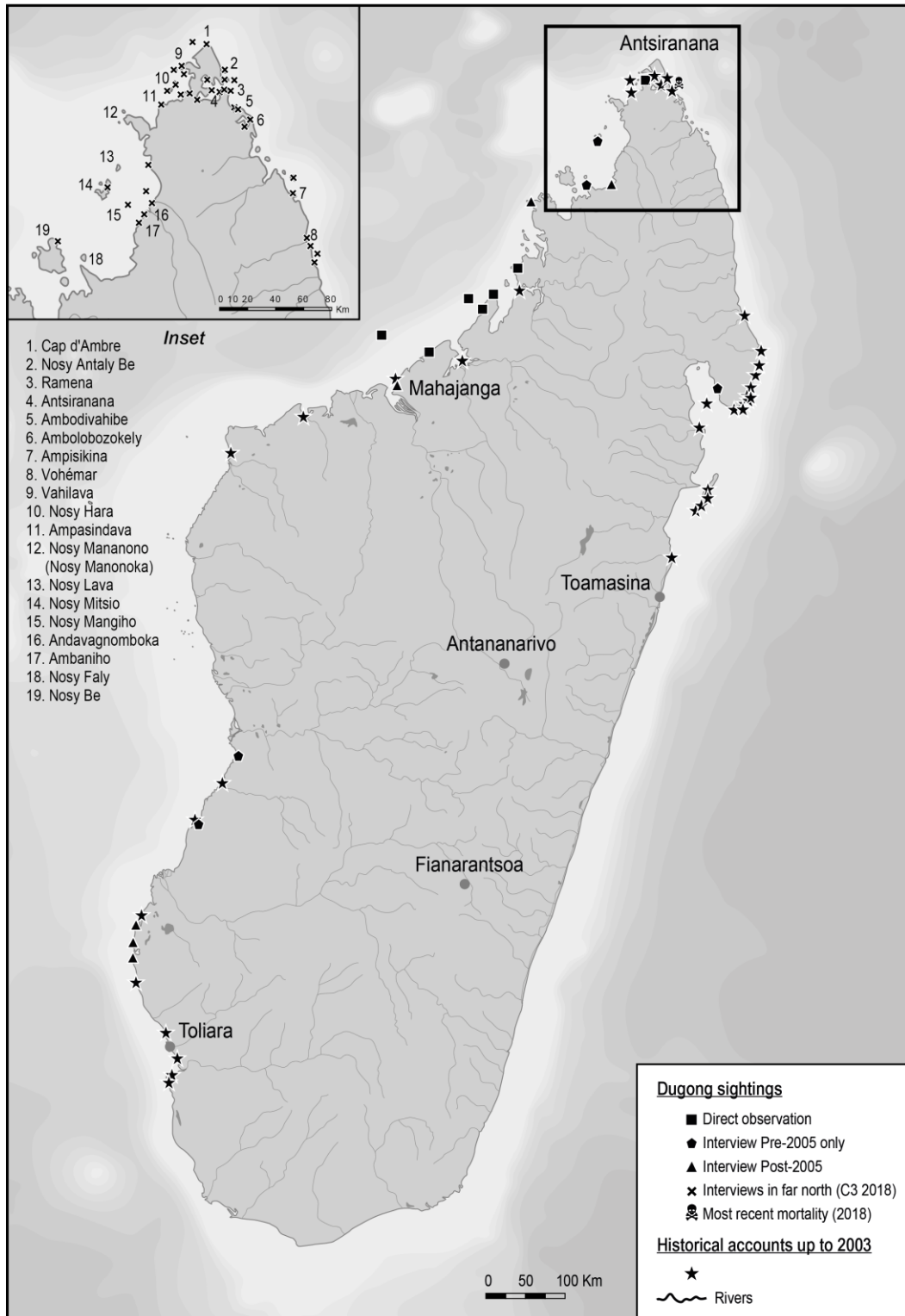


Figure 3. Occurrence of *Dugong dugon* in Madagascar waters based on survey data (C3 Madagascar and Indian Ocean Islands Programme 2010b; Van Canneyt et al. 2010; Cerchio et al. 2012) and historical observations (Table 4).