

# *The New Natural History of Madagascar*

Steve M. Goodman, Editor

## Chapter 7 – Marine and Coastal Ecosystems

### Citation

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## CETACEAN SPECIES DIVERSITY IN MALAGASY WATERS

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Cetacea is the group of marine mammals that encompasses all whales, dolphins, and porpoises. The group is nested within the Mammalian Order Cetartiodactyla (comprising all artiodactyls, or even-toed ungulates, and cetaceans), with the family Hippopotamidae being the most likely sister group (Geisler and Uhen 2005). The Committee on Taxonomy of the Society for Marine Mammalogy recognizes 91 species of cetaceans in the world, including 14 Mysticeti (baleen whales) and 77 Odontoceti (toothed whales, dolphins, and porpoises) of which one, *Lipotes vexillifer*, the Yangtze River Dolphin, is likely extinct (Committee on Taxonomy 2020).

Previous assessment of the species diversity of cetaceans in Malagasy waters (Rosenbaum 2003) indicated only 12 species whose presence could be considered confirmed (three Mysticetes and nine Odontocetes), and an additional 13 species that were suspected or occurred elsewhere in the region (four Mysticetes and nine Odontocetes). Very little information existed prior to that review, and thus it was based primarily upon limited published studies focusing on single species, a few unpublished studies that targeted description of biodiversity, and anecdotal accounts. Since 2005, there have been several research groups targeting assessment of cetacean diversity in Malagasy waters that have substantially advanced our understanding, including small-boat-based work in the southwest region (Anakao) between 2005 and 2013, and the northwest region (Nosy Be) between 2008 and 2017 (Cerchio et al. 2009a, 2014, 2015a, 2015b; S. Cerchio et al., unpublished data); ecotourism surveys off Ile Sainte Marie, Mahajanga, Ifaty, and Tolagnaro between 2009 and 2019 (A. Saloma and F. X. Mayer, unpublished data); aerial surveys covering northwest, mid-west, southwest, and northeast coasts between mid-December 2009 and early January 2010 (“REMMA”; Van Canneyt et al. 2010; Laran et al. 2017); and long-term passive acoustic monitoring along the west coast between 2015 and 2019 (Cerchio et al. 2018; S. Cerchio and T.

Rasoloarijao, unpublished data). We draw primarily upon these different surveys, with several additional studies and anecdotal accounts, to report the confirmed presence of 26 different species, including eight Mysticeti and 18 Odontoceti (Table 7-16). Based on accounts from adjacent areas and the availability of habitat, we infer the likely presence of at least an additional three species and the possible presence of two others. There is some overlap with the species reported in Rosenbaum (2003) but also new inclusions, and exclusions of several species due to insufficient evidence.

We report the diversity of cetaceans geographically according to the four Marine Ecoregions that are proposed in the “Plan stratégique de gestion du réseau d’Aires Protégées de Madagascar National Parks – 2014-2024” (see Cooke et al., 2022) and originally based upon Obura et al. (2012). These include the North Mozambique Channel Ecoregion, the South Mozambique Channel Ecoregion, the South Madagascar Ecoregion, and the East Madagascar Ecoregion. To the extent that available data allows, we describe in the subsequent sections the diversity of cetaceans for each of these Marine Ecoregions (Table 7-16). We define Malagasy waters as falling within Madagascar’s Exclusive Economic Zone (EEZ); however, when the Madagascar EEZ abuts the EEZ of another territory within 200 nm of the Madagascar coast, e.g., France (Mayotte, Iles Glorieuses) and The Union of the Comoros, we consider accounts from the adjoining EEZ to maintain geographic consistency (i.e., within a 200 nm swath around Madagascar). In some cases we draw upon information outside of the 200 nm distance when informative as regards adjacent Madagascar waters for which data are lacking (e.g., observations on the Madagascar Ridge to the south of the Madagascar EEZ). Other contributions herein on Cetacea in Malagasy waters include one on *Megaptera novaeangliae* (Humpback Whale) (see Rosenbaum and Chou, 2022) and *Balaenoptera omurai* (Omura’s Whale) (see Cerchio et al., 2022).

## MARINE AND COASTAL ECOSYSTEMS

TABLE 7-16. Cetacean species occurrence around Madagascar, subdivided by ecoregion, and categorized by confidence of occurrence in Malagasy waters

SCIENTIFIC NAME	COMMON NAME (ENGLISH)	ECOREGION				MADAGASCAR OVERALL
		NORTH MOZAMBIQUE CHANNEL	SOUTH MOZAMBIQUE CHANNEL	SOUTH MADAGASCAR	EAST MADAGASCAR	
<b>MYSTICETI</b>	<b>BALEEN WHALES</b>					
<b>Balaenopteridae</b>	<b>Rorquals</b>					
<i>Balaenoptera musculus intermedia</i>	Antarctic Blue Whale	X	X	*	*	X
<i>B. m. breviceuda</i>	Pygmy Blue Whale	X	X	X	*	X
<i>B. physalus</i>	Fin Whale	X	X	*	*	X
<i>B. borealis</i>	Sei whale	?	?	*	?	*
<i>B. edeni</i>	Bryde's Whale		?	X	*	X
<i>B. omurai</i>	Omura's Whale	X	X			X
<i>B. bonaerensis</i>	Antarctic Minke Whale	X	X	*	*	X
<i>B. acutorostrata</i> ssp.	Dwarf Minke Whale	X	?	?		X
<i>Megaptera novaeangliae</i>	Humpback Whale	X	X	X	X	X
<b>Balaenidae</b>	<b>Right whales</b>					
<i>Eubalaena australis</i>	Southern Right Whale	?	X	X	X	X
<b>ODONTOCETI</b>	<b>TOOTHED WHALES AND DOLPHINS</b>					
<b>Physeteridae</b>	<b>Sperm whales</b>					
<i>Physeter macrocephalus</i>	Sperm Whale	X	X	X	X	X
<b>Kogiidae</b>	<b>Kogiid sperm whales</b>					
<i>Kogia sima</i>	Dwarf Sperm Whale	X	X	*	*	X
<i>K. breviceps</i>	Pygmy Sperm Whale	X	*	*	*	X
<b>Ziphiidae</b>	<b>Beaked whales</b>					
<i>Ziphius cavirostris</i>	Cuvier's Beaked Whale	X	X	X	X	X
<i>Mesoplodon densirostris</i>	Blainville's Beaked Whale	*	*	?	?	*
<i>M. eueu</i>	Ramari's Beaked Whale		?	*	?	*
<i>M. ginkgodens</i>	Ginkgo-toothed Beaked Whale	?	?		?	?
<i>Indopacetus pacificus</i>	Longman's Beaked Whale	X	*	*	X	X
<b>Delphinidae</b>	<b>Dolphins</b>					
<i>Sousa plumbea</i>	Indian Ocean Humpback Dolphin	X	X	X		X
<i>Tursiops aduncus</i>	Indo-Pacific Bottlenose Dolphin	X	X	*	X	X
<i>T. truncatus</i>	Common Bottlenose Dolphin	X	X	X	*	X
<i>Steno bredanensis</i>	Rough-toothed Dolphin	?	X	?	?	X
<i>Stenella longirostris</i>	Spinner Dolphin	X	X	*	X	X
<i>S. attenuata</i>	Pantropical Spotted Dolphin	X	X	*	X	X
<i>S. coerulealba</i>	Striped Dolphin	*	*	X	X	X
<i>Lagenodelphis hosei</i>	Fraser's Dolphin	X	X	*	X	X
<i>Grampus griseus</i>	Risso's Dolphin	X	X	*	X	X

## SYSTEMATIC ACCOUNTS- CETACEAN SPECIES DIVERSITY IN MALAGASY WATERS

SCIENTIFIC NAME	COMMON NAME (ENGLISH)	ECOREGION				MADAGASCAR OVERALL
		NORTH MOZAMBIQUE CHANNEL	SOUTH MOZAMBIQUE CHANNEL	SOUTH MADAGASCAR	EAST MADAGASCAR	
<i>Peponocephala electra</i>	Melon-headed Whale	X	X	X	X	X
<i>Feresa attenuata</i>	Pygmy Killer Whale	?	?	?	?	?
<i>Pseudorca crassidens</i>	False Killer Whale	X	X	*	X	X
<i>Globicephala macrorhynchus</i>	Short-finned Pilot Whale	X	X	X	X	X
<i>Orcinus orca</i>	Killer Whale	X	X	*	*	X

Notes: X, confirmed to occur in Madagascar waters; \*, likely to occur in Madagascar waters based upon other accounts; ?, unknown but possible to occur in Madagascar waters based on occurrence in the region. Species are listed by taxonomic families within Mysticeti and Odontoceti. Rosenbaum (2003) included four additional species as “suspected or probable occurrence” or “unknown but has been recorded in the region”; however, to the best of our knowledge there is currently no substantiated evidence for them in Madagascar waters and have thus excluded: *Caperea marginata* (Pygmy Right Whale); *Delphinus tropicalis* (Common Dolphin); *Mesoplodon hectori* (Hector's Beaked Whale); and *Globicephala melas* (Long-finned Pilot Whale).

### THE NORTH MOZAMBIQUE CHANNEL MARINE ECOREGION (EXCLUDING THE NORTHEAST COAST OF MADAGASCAR)

The northwestern coast of Madagascar is a major component of the North Mozambique Channel Ecoregion and includes the stretch of coast from Cap d’Ambre, the northern tip of Madagascar, to Cap Saint André, approximately 700 km or one-third of Madagascar’s west coast (Obura et al. 2019). It is characterized by a moderately wide continental shelf ranging from 30 to 60 km, fringed by multiple estuaries, embayments, and several archipelagos including over 150 small near-shore islands. Consequently, there is a large variety of habitats from coastal (including mangroves, coral reefs, and sandy and rocky shores), neritic continental shelf, to pelagic deep-water. This is a highly diverse and important region for marine mammals encompassing important habitat for breeding, feeding, and migration, as well as small and resident populations for several cetacean species. The area includes the Nosy Be region from approximately 12.7°S to 13.7°S, including Nosy Be, Nosy Komba, Nosy Iranja, and the Nosy Mitsio Archipelago, where several research programs focused on marine mammals have been conducted over the past 12 years. A minimum of 23 cetacean taxa (22 species, one represented by two different subspecies) have been recorded along this 600 km stretch of coast (Table 7-16) including six baleen whales, 16 toothed whales and dolphins, and an additional two species likely and five species possibly to occur (Van Canneyt et al. 2010; Cerchio et al. 2014, 2018). In addition, *Dugong dugon* (Dugong) has been documented in this region rather extensively, indicating important habitat for this vulnerable and locally endangered marine mammal (see Davis et al., 2022).

#### Cetaceans in the North Mozambique Channel Marine Region

**Mysticetes, baleen whales:** *Balaenoptera musculus* (Blue Whales) in the Southern Hemisphere are divided into at least two subspecies with overlapping distributions, and the different

populations are distinguished by diagnostic song-types (McDonald et al. 2006; Branch et al. 2007). The subspecies *B. m. intermedia* (Antarctic Blue Whale; IUCN Red List: Critically Endangered, Cooke 2018a) is circumpolar distributed and are estimated to be approximately 6500 total individuals for the Southern Hemisphere, or less than 2% of their pre-whaling abundance. The subspecies spends Austral summers at high latitudes along the Antarctic ice edge from where the most extensive data are available. *Balaenoptera m. intermedia* migrate to winter habitat in low latitudes according to patterns that are still poorly understood at a global level. Winter habitat is presumably occupied during the breeding season and includes the tropical and subtropical Indian Ocean (or largely north of 30°S; Branch et al. 2007), but little data exist. The Antarctic subspecies is defined by a single song-type, which has been documented in all Southern Hemisphere ocean basins. Passive acoustic monitoring from the shelf slope near Nosy Be indicated the presence of *B. m. intermedia* song off northwest Madagascar throughout the Austral winter from June to September, suggesting the existence of previously unrecognized breeding season habitat (Cerchio et al. 2018). Some loud acoustic detections indicated presence of *B. m. intermedia* within 10 km of the shelf edge, whereas most individuals were likely within 100 km of the coast, and it is likely that whales range further offshore into the Mozambique Channel.

The subspecies *B. m. breviceauda* (Pygmy Blue Whale; IUCN Red List: Endangered, Cooke 2018b) is divided into at least four populations in the Indian Ocean, each with diagnostic song-types and regional distribution. Passive acoustic monitoring off Nosy Be indicated the extensive documentation of the southwest Indian Ocean (SWIO) population song-type in the deep offshore waters, with similar offshore spatial distribution to *B. m. intermedia* (Cerchio et al. 2018). The SWIO *B. m. breviceauda* song occurred in prominent bi-modal peaks of singing activity during May-July and October-January, suggesting the existence of a previously unrecognized migratory corridor between summer feeding and winter breeding grounds south and north of Madagascar, respectively. This migratory corridor likely connects feeding habitat on the Madagascar Ridge (Best et al. 2003) with putative breeding habitat off Kenya and the Seychelles area (Branch

## MARINE AND COASTAL ECOSYSTEMS

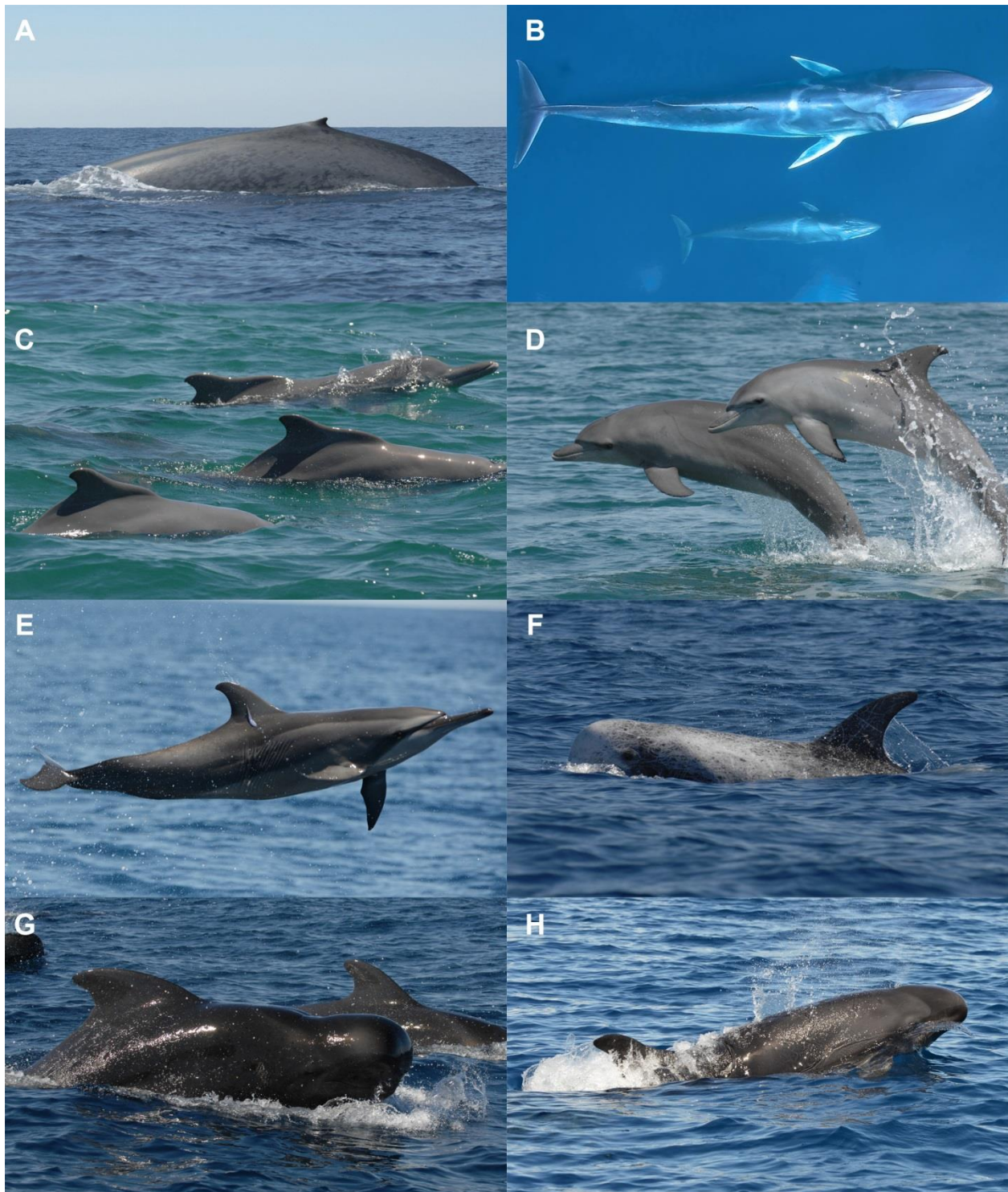


FIGURE 7-28. Examples of cetacean species found in Malagasy waters and discussed in this chapter: A) *Balaenoptera musculus brevicauda*, photographed offshore Nosy Be near to 2000 m depth contour; B) *B. omurai* mother and calf, photographed by drone in neritic shelf waters north of Nosy Be; C) *Sousa plumbea* photographed in coastal waters of Nosy Be; D) *Tursiops aduncus* photographed in coastal waters of Nosy Be; E) *Stenella longirostris* photographed off Nosy Be; F) *Grampus griseus* photographed off Anakao; G) *Globicephala macrorhynchus* photographed off Anakao; and H) *Pseudorca crassidens* photographed in neritic waters of Nosy Be. (PHOTO A by N. Andrianarivelo; B-H by S. Cerchio.)

et al. 2007; Barber et al. 2016). The songs of two other *B. m. brevicauda* populations were also documented off Nosy Be, those of the central Indian Ocean population and northwestern Indian Ocean/Arabian Sea population, with far fewer detections, indicating either vagrant individuals, or that Nosy Be lies at the geographical limits of these two populations (Cerchio et al. 2018, 2020).

*Balaenoptera physalus* (Fin Whale) and *B. bonaerensis* (Antarctic Minke Whale) are circumpolar distributed in cold waters of high latitudes during the Austral summer, and are thought to migrate to poorly understood winter ranges in tropical and warm temperate low latitudes during the Austral winter breeding season, similar to *B. m. intermedia*. Acoustic monitoring offshore of Nosy Be indicated presence of *B. physalus* during the late Austral winter, from early August to mid-September (Cerchio et al. 2018) representing the first confirmed documentation of the species in Madagascar waters. The timing of *B. physalus* song suggests a later arrival than *B. m. intermedia* and a lower rate of occurrence and occupancy, suggesting the northern extent of breeding habitat. *B. bonaerensis* song was very commonly recorded off Nosy Be from early July to early December, therefore remaining seasonally later than *B. m. intermedia* or *B. physalus*, and suggesting breeding season habitat. *Balaenoptera acutorostrata* ssp. (Dwarf Minke Whale) is an as yet unnamed Southern Hemisphere subspecies of *B. acutorostrata* (Common Minke Whale) with a distribution and migration pattern that is poorly studied, but found in shallow low latitude shelf habitat during Austral winter in several regions around the globe, including eastern Africa. Song vocalizations of *B. acutorostrata* ssp. were detected on several days during non-systematic review of acoustic data from continental shelf waters around Nosy Be; it is possible that future analyses will indicate regular presence during the Austral winter, and thus breeding habitat (S. Cerchio and B. Andrianantenaina, unpublished data). For both *B. bonaerensis* and *B. acutorostrata* ssp., these data represent the first confirmation of species-level identification in Madagascar waters. In addition to this acoustic evidence, during REMMOA aerial surveys there was a single sighting of a Minke Whale of unidentified species off the northwest coast in deep water, and one close to Comoros (Van Canneyt et al. 2010).

*Balaenoptera omurai* (Omura's Whale) is the most recently named species of baleen whale in the world (Wada et al. 2003) and work off Nosy Be documented the first detailed description of the species globally (Cerchio et al. 2015a, 2019; see Cerchio et al., 2022). These recent data indicate that this is a resident and non-migratory population with a restricted range in the northwest and central west coasts of Madagascar, and may be isolated within a fragmented oceanic/global range for the species.

Madagascar is a well-documented breeding area for the southwest Indian Ocean population of *Megaptera novaeangliae* (Humpback Whale), distributed throughout all coastal waters during the Austral winter (Fossette et al. 2014; Cerchio et al. 2016; Dulau et al. 2017). Small boat surveys indicate that they are common in coastal waters of the Nosy Be region during the mid to late breeding season, and year-long acoustic monitoring in the deep offshore waters of the Nosy Be region indicated near continuous presence of *M. novaeangliae* song from early July to mid-November (Cerchio et al. 2018; S. Cerchio and T. Rasoloarijao, unpublished data). Satellite telemetry data indicated

that this area of coast is a late season migratory corridor for *M. novaeangliae* during the southern migration to polar waters (Fossette et al. 2014; Dulau et al. 2017).

**Odontocetes, toothed whales and dolphins:** *Sousa plumbea* (Indian Ocean Humpback Dolphin) (IUCN Red List: Endangered, Braulik et al. 2015, 2017) is widely distributed along the west coast of Madagascar (Razafindrakoto et al. 2004; Cerchio et al. 2015b). There is confirmed documentation of *S. plumbea* in several northwest locales: in the far northwest off Nosy Be and Nosy Mitsio (Robineau and Rose 1984; Cockcroft and Young 1998; Cerchio et al. 2015b); on the lower-northwest coast in the Loza Lagoon system, approximately 150 km north of Mahajanga (Collins et al. 2009), and off Mahajanga (Cockcroft and Young 1998; Razafindrakoto et al. 2004); and during aerial surveys along extensive stretches of coast between Mahajanga and Nosy Be (Van Canneyt et al. 2010). All *Sousa* spp. are obligate shallow water species, and off Nosy Be and Nosy Iranja all encounters with *S. plumbea* occurred in depths of <25 m, with average depths of 8.2 m and 10.5 m, respectively (Cerchio et al. 2015b). *Tursiops aduncus* (Indo-Pacific Bottlenose Dolphin) is also commonly encountered in the coastal waters of Nosy Be, Nosy Iranja, and Nosy Mitsio, and often in association with *S. plumbea*, however their habitat is more diverse being found in coastal habitat as well as neritic continental shelf habitat (Cerchio et al. 2014, 2015b). They are also commonly encountered off Mahajanga (A. Saloma and F. X. Mayer, unpublished data), and are likely distributed along the entire northwest coast.

*Stenella longirostris* (Spinner Dolphin) was the most often sighted species of Odontocete by number of individuals in the continental slope and offshore areas during small-boat surveys off Nosy Be (Cerchio et al. 2014). *Stenella attenuata* (Pantropical Spotted Dolphin) was frequently sighted in the offshore areas during surveys around Nosy Be, at times in groups exceeding 500 individuals, and in combination with *S. longirostris*, as well as on the continental shelf in smaller-sized groups (Cerchio et al. 2014; S. Cerchio et al., unpublished data). *Stenella longirostris* were also commonly encountered off Mahajanga by an ecotourism and fishing operator, and more rarely *S. attenuata* (V. E. Bedier, unpublished data). *Stenella coeruleoalba* (Striped Dolphins) have been reported by an ecotourism group off Mahajanga (A. Saloma and F. X. Mayer, unpublished data), and there is one documented stranding on Mayotte (Van Canneyt et al. 2011); however, the species appears to be rare around Madagascar given an absence of encounters in dedicated surveys, and some reports may represent confusion with other *Stenella* sp., so for this region we consider it a likely but unconfirmed species.

Densities of Odontocetes were estimated in a surveyed area within this ecoregion during the REMMOA aerial survey conducted in the Southwest Indian Ocean region; in most cases similar-sized species were lumped into species groups since it was not always possible to identify to the species level. Density of small Delphininae (likely *S. longirostris* and *S. attenuata*) was estimated at 18 individuals per 100 km<sup>2</sup> in the neritic, slope, and oceanic waters along the northwest coast (Laran et al. 2017; S. Laran et al., unpublished data). Large groups of *Lagenodelphis hosei* (Fraser's Dolphins), in excess of 100 individuals, were occasionally encountered in deep waters around Nosy Be, as were small groups of *Tursiops truncatus* (Common Bottlenose

Dolphins) offshore form (Cerchio et al. 2014; S. Cerchio et al., unpublished data). For large Delphininae (potentially *T. truncatus*, *S. plumbea* or *L. hosei*) density was estimated during REMMOA surveys at about seven individuals per 100 km<sup>2</sup> in the waters of the neritic, slope area along northwest coast of Madagascar (Laran et al. 2017).

Among the “blackfish” species (subfamily Globicephalinae), *Globicephala macrorhynchus* (Short-finned Pilot Whale) with groups of up to more than 40 individuals have been sighted offshore of Nosy Be, along with similarly moderate-sized groups of *Peponocephala electra* (Melon-headed Whale) and *Pseudorca crassidens* (False Killer Whale) (Cerchio et al. 2014; S. Cerchio et al., unpublished data). Off Mahajanga, large groups of *P. crassidens* and *Peponocephala electra* (in excess of 100 individuals) have been reported, along with a single very rare encounter with *Orcinus orca* (Killer Whale) (a group of three, including adult male, female, and juvenile) in deep offshore waters (V. E. Bedier, unpublished data, with photographic documentation). Large groups of *P. electra*, were encountered during REMMOA aerial survey resulting in a density of small Globicephalinae (likely *P. electra*, but potentially *Pseudorca crassidens*) of up to 50 individuals per 100 km<sup>2</sup> for oceanic waters off northwest Madagascar, similar to the value obtain for the Comoros Archipelago (Laran et al. 2017). A mass stranding of ca. 200 *Peponocephala electra* occurred in the Loza Lagoon system in 2008, likely related to petroleum exploration activities (Collins et al. 2009; Southall et al. 2013). *Feresa attenuata* (Pygmy Killer Whale) have not been confirmed in Malagasy waters; however, four individuals stranded in the nearby Glorieuses Islands in 2016 (Dars et al. 2018) and one small group was sighted off Mayotte (Kiszka et al. 2010a), suggesting they may be present in low numbers and requiring documentation. A single group of *Grampus griseus* (Risso’s Dolphins) was encountered south of the Radama Islands during REMMOA surveys, but their density was low compared to other species, around 0.6 individuals per 100 km<sup>2</sup>. *Grampus griseus* have also been documented with relatively low encounter rate off Mayotte (Kiszka et al. 2007, 2010a), so although their presence has been documented in the northern Mozambique Channel, their occurrence appears to be much less than in the southern Mozambique Channel (see below).

The families Ziphiidae (Beaked whales) and Kogiidae (Kogiid sperm whales) are offshore deep water species that are rarely observed and notoriously difficult to document. Groups of *Ziphius cavirostris* (Cuvier’s Beaked Whale) have been sighted on the slope off Nosy Be on two occasions (Cerchio et al. 2014; S. Cerchio, unpublished data) and during the REMMOA aerial survey (Van Canneyt et al. 2010). An individual *Indopacetus pacificus* (Longman’s Beaked Whale) was sighted off Nosy Be during the REMMOA aerial survey, and close to the Comoros coast, confirming previous sightings on the shelf waters of this island (Anderson et al. 2006, Kiszka et al. 2010b). *Mesoplodon densirostris* (Blainville’s Beaked Whale) is a primarily warm water species that is widely distributed in the tropics around the world; there is documentation of the species off Mayotte and Comoros (Kiszka et al. 2007, 2010a, 2010b; Van Canneyt et al. 2010) and given the proximity and similar habitat it is likely found in the deep offshore waters of northwest Madagascar. Beaked whales as a group (including *Z. cavirostris*, *I. pacificus* and unidentified ziphiid) were estimated at a density of 0.4 individuals

per 100 km<sup>2</sup> during REMMOA surveys in the northern Mozambique Channel, relatively high compared to other surveyed areas (Laran et al. 2017). Unidentified *Kogia* sp. were sighted during REMMOA surveys with maximum abundance estimated for the northern Mozambique Channel (0.08 individuals per 100 km<sup>2</sup>, Laran et al. 2017). A *K. breviceps* (Pygmy Sperm Whale) live-stranded on Nosy Be in 2019 (MadaMegafauna, unpublished data, with photographic documentation). A *K. sima* (Dwarf Sperm Whale) stranded in the nearby Glorieuses Islands (Dorémus et al. 2009) and two were sighted off Mayotte (Kiszka et al. 2010a), so it is clear that both *Kogia* species occur in these waters.

*Physeter macrocephalus* (Sperm Whale; IUCN Red List: Vulnerable, Taylor et al. 2019) were historically hunted in the region (Townsend 1935); however, they have not been a focus of study in the waters of northwest Madagascar. The species uses the deep offshore waters of the region regularly and were encountered over the slope habitat during REMMOA aerial survey in groups of up to four individuals (Van Canneyt et al. 2010). Boat surveys off Nosy Be resulted in several encounters near the 2000 m depth contour including groups of up to nine individuals, and acoustic monitoring produced numerous, but as-yet unquantified, detections of *P. macrocephalus* clicks (Cerchio et al. 2014; S. Cerchio and T. Rasoloarijao, unpublished data).

## THE SOUTH MOZAMBIQUE CHANNEL MARINE ECOREGION

The South Mozambique Channel Ecoregion includes the central west and southwest coast of Madagascar from Cap Saint André to roughly Itampolo, approximately 1000 km of the west coast (Obura et al. 2019). The ecoregion encompasses diverse marine habitats, including coastal, continental shelf, continental slope, and peri-insular and seamount habitat around the oceanic islands of Juan de Nova, Europa, and Bassas de India atolls. The continental shelf of Madagascar is at its broadest extent just south of Cap Saint André at about 100 km, and progressively narrows to the south to just a few kilometers from the coast, north of the city of Toliara. The region to the south of Toliara has several notable features that provide habitat for a diverse assemblage of cetaceans. The Grand Recif de Toliara is one of the largest barrier reef systems in the Indian Ocean, extending from north of Toliara to the village of Saint Augustin. The reef is made up of barrier and fringing reefs and extensive lagoons, including mangroves inside the main lagoon of the Grand Recif. At the southern end of the Grand Recif lies the Saint Augustin Submarine Canyon. The combination of the canyon cutting through the shelf and geological faulting brings deep water very close to the coast, providing suitable habitat for typically deep-water species. South of the canyon, the shelf is relatively narrow with a steep slope, from the village of Anakao as far south as Itampolo.

A high diversity of cetaceans is found in the Malagasy waters of the southern Mozambique Channel with at least 21 species documented (Table 7-16), including six Mysticetes and 15 Odontocetes, during small-boat surveys and acoustic monitoring in the Toliara area, and aerial surveys over a more extensive portion of the region (Cerchio et al. 2009a; Van Canneyt et al. 2010; S. Cerchio and N. Andrianarivelo, unpublished data; A. Saloma and F. X. Mayer, unpublished data). An additional four

species are considered likely to occur and six species possibly to occur (Table 7-16). Therefore the southern Mozambique Channel clearly has high cetacean richness (Laran et al., 2017) with the Toliara/Saint Augustin Submarine Canyon area being a particular hotspot (S. Cerchio and N. Andrianarivelo, unpublished data).

### Cetaceans in the South Mozambique Channel Marine Ecoregion

**Mysticetes:** Based upon the presence of *Balaenoptera musculus intermedia* song off the northwest coast of Madagascar during the Austral winter (Cerchio et al. 2018), it is certain that the species migrates through the Mozambique Channel and past this area. Preliminary findings from passive acoustic monitoring during Austral summer and autumn off Toliara has confirmed the presence of *B. m. intermedia* song at least during late March and April, presumably during the northward migration from the Antarctic (S. Cerchio and T. Rasoloarijao, unpublished data). Similarly, the SWIO population of *B. m. brevicauda* migrates through this area, based upon the bimodal seasonal presence of their song off the northwest coast of Madagascar (Cerchio et al. 2018). Recent passive acoustic monitoring from Toliara has confirmed the presence of their song during at least November to late January, presumably the end of the southward migration to the Madagascar Ridge, and during late March to April, presumably the beginning of the northward migration to breeding areas (S. Cerchio and T. Rasoloarijao, unpublished data). In addition to the two *B. musculus* ssp., *B. physalus* and *B. bonaerensis* were also detected during the austral spring/summer (S. Cerchio and T. Rasoloarijao, unpublished data) likely on migration through this area, as they have also been acoustically detected off northwest Madagascar during the austral winter (Cerchio et al. 2018). *Balaenoptera physalus* were also encountered in the austral autumn (end of April) offshore in the southern Mozambique Channel near Europa Island during an oceanic ship survey (Dorémus et al. 2009).

*Megaptera novaeangliae* are commonly seen between July and September off the southwest coast of Madagascar, utilizing the area for breeding habitat. The Toliara/Saint Augustine Submarine Canyon/Anakao area is an active breeding area for this species, as evidenced by small-boat surveys (Cerchio et al. 2009a; S. Cerchio and N. Andrianarivelo, unpublished data) and satellite telemetry data (Cerchio et al. 2016; Trudelle et al. 2016). Breeding behavior was regularly observed during Austral winter boat surveys, including singing, mothers with young calves, and competitive groups of males following a female. Satellite tracks of 11 whales tagged off Anakao indicated extensive movement through this region and along the southern coast of Madagascar to Tolagnaro. Satellite telemetry studies have documented migratory movements through the Mozambique Channel (Fossette et al. 2014; Cerchio et al. 2016; Trudelle et al. 2016); at least one *M. novaeangliae* tagged off Anakao transited nearly to Europa Island ca. 270 km offshore before the tag stopped transmitting (Cerchio et al. 2016).

*Eubalaena australis* (Southern Right Whale) have been rarely sighted in the waters of Madagascar, but there have been three documented sightings during boat surveys off Anakao and Ifaty, one of which was a mother-calf (Cerchio et al. 2009a; S. Cerchio and N. Andrianarivelo, unpublished data; A. Saloma and F. X.

Mayer, unpublished data). In general, *E. australis* are sighted infrequently but regularly around Madagascar, with anecdotal sightings on both the west and east coasts; it is unclear whether these individuals represent range expansion from the South Africa population, or potentially represent remnants of an historical and near-extirpated population from Mozambique/ Madagascar (Rosenbaum et al. 2001; Banks et al. 2011), that was heavily hunted off the Crozet Islands (Townsend 1935).

**Odontocetes:** The region contains important habitat for small coastal populations of *Sousa plumbea* and *Tursiops aduncus*. Both species have been documented along the entire coast of this region, based on a combination of boat-based data (off Anakao, Andavadoake, Belo sur Mer, and the Barren Islands) and aerial survey observations (off the central and southwestern coast), and reports from extensive socio-ecological interviews with local fishers at 10 locales spread throughout the region (Cerchio et al. 2015b). As reported for the northwest, *S. plumbea* prefer very nearshore shallow habitat, whereas *T. aduncus* are encountered more widely across neritic shelf waters.

Aside from *S. plumbea* and *T. aduncus*, *Grampus griseus* were the most frequently sighted Odontocete during boat-based surveys off Anakao (Cerchio et al. 2009a; S. Cerchio and N. Andrianarivelo, unpublished data), as well as off Ifaty (A. Saloma and F. X. Mayer, unpublished data). *Stenella longirostris* and *S. attenuata* were also frequently sighted off Anakao, at times in large (200-500 individuals) mixed-species groups (Cerchio et al. 2009a; S. Cerchio and N. Andrianarivelo, unpublished data). Vevo fishers practiced drive-hunts on pods of *S. longirostris* during periods when groups were resting near to reefs off Anakao, at times taking 100-200 individuals in a single hunt (Andrianarivelo 2001; Cerchio et al. 2009a, 2014). *Globicephala macrorhynchus* were also relatively frequently sighted off Anakao; recent mitogenomic and nuclear single nucleotide polymorphism analyses indicated that Madagascar populations of this species are nested within the “Naisa” form along with other Indian and West Pacific Ocean populations, which was recommended to be recognized as a distinct subspecies (Van Cise et al. 2019). Less frequently sighted species off Anakao included *T. truncatus*, *Lagenodelphis hosei*, *Steno bredanensis* (Rough-Toothed Dolphin), *Peponocephala electra*, and *Pseudorca crassidens*. *Orcinus orca*, along with *G. griseus*, *L. hosei* and *Globicephala macrorhynchus* have been sighted off Ifaty (A. Saloma and F. X. Mayer, unpublished data). An *O. orca* was also reported stranded near Toliara (Andrianarivelo 2001).

During REMMOA aerial surveys, two surveyed blocks were included in this ecoregion, off the central west coast from Maintirano extending to Juan de Nova Island waters, and off the southwest coast from Toliara extending to Europa Island and Bassas da India atolls. The most abundant species were large Delphininae (mostly *T. truncatus* and some *T. aduncus*, lumped as *Tursiops* spp.) with a relative density of 27 and 17 individuals per 100 km<sup>2</sup> in the central and south area, respectively, preferring oceanic waters with smaller groups over the shelf and larger offshore (Laran et al. 2017). Dorémus et al. (2009) also noted large groups of *T. truncatus* during oceanic boat surveys offshore near to and south of Juan de Nova. During REMMOA, small Delphininae (likely *Stenella* spp.) were mostly encountered in the central area with 19 individuals per 100 km<sup>2</sup>, compared to three

## MARINE AND COASTAL ECOSYSTEMS

individuals per 100 km<sup>2</sup> in the south area, with maximum density on the shelf. Small Globicephalinae (mostly *Peponocephala electra*) also preferred the central area on the slope habitat with density estimates of 20 individuals per 100 km<sup>2</sup>, compared to six individuals per 100 km<sup>2</sup> in the south area, and were encountered in both areas in large groups (Laran et al. 2017). Large Globicephalinae (mostly *Pseudorca crassidens* and some *G. macrorhynchus*) had a relative density of 2-3 individuals per 100 km<sup>2</sup> in both surveyed areas, which was the second highest densities encountered in the southwest Indian Ocean after the Seychelles. *Grampus griseus* density was similarly around 2.5 and 2.1 individuals per 100 km<sup>2</sup> in both surveyed areas, and was the highest density for the species throughout the southwest Indian Ocean (Laran et al. 2017), as well as for all tropical areas surveyed by the REMMOA project (including the West Indies, French Guiana, French Polynesia, New Caledonia, and Wallis and Futuna).

Numerous *Ziphius cavirostris*, unidentified *Mesoplodon* sp. and other unidentified ziphiid groups were observed during REMMOA surveys in this region. Densities for the species group were about 0.5 individuals per 100 km<sup>2</sup> in the central and southern blocks; these were the highest densities observed for this species group throughout the southwest Indian Ocean (Laran et al. 2017). *Physeter macrocephalus* and *Kogia* sp. were also sighted during REMMOA, but each with an estimated density one order of magnitude less than beaked whales (without correcting for the availability bias due to dive duration of this species). *Physeter macrocephalus* were historically hunted in the area (Townsend 1935), so might be expected to be more numerous than suggested by the aerial surveys. This species was acoustically detected during boat surveys off Anakao, and preliminary results of recent acoustic monitoring south of Toliara (on the north slope of the Saint Augustine Submarine Canyon) recorded frequent *P. macrocephalus* clicks between at least November and April (Cerchio et al. 2009a; S. Cerchio and T. Rasoloarijao, unpublished data); therefore, further work may reveal a more prominent presence. A single *K. sima* was identified during boat-based surveys off Anakao in the Saint Augustin Submarine Canyon, confirming the presence of the species (S. Cerchio and T. Andrianavelo, unpublished data), but it is not clear if *K. breviceps* also occur, and the REMMOA *Kogia* sightings were not identified to the species level (Van Canneyt et al. 2010).

### THE SOUTH MADAGASCAR MARINE ECOREGION (INCLUDING THE DEEP SOUTH)

The South Madagascar Ecoregion, encompasses approximately 500 km of coastline from Itampolo on the southwest coast to just north of Tolagnaro on the southeast coast, and includes the area known as the “Deep South”. The neritic habitat of this ecoregion is characterized by a broad continental shelf that extends ca. 80 km south of Cap Sainte Marie, the most southern point on Madagascar. Beyond this the Madagascar Ridge extends further south some 800 km to the Walters Shoals and beyond. This is a very poorly researched area for marine mammals, with a paucity of data for even the nearshore coastal region. We draw here upon a combination of anecdotal reports in the nearshore waters and few surveys that occurred in the offshore deep water regions

primarily beyond the Madagascar shelf (Kasuya and Wada 1996; Best 2001, 2007; Best et al. 2003; Dorémus et al. 2009; Gadenne and Saloma 2017; Ternon et al. 2018). Despite the lack of research effort compared to other areas of Madagascar, 11 cetacean species were confirmed to occur in this ecoregion, including four Mysticetes and seven Odontocetes, with at least an additional 14 considered likely and four considered possibly to occur (Table 7-16).

### Cetaceans in the South Madagascar Ecoregion

**Mysticetes:** The SWIO population of *Balaenoptera musculus breviceuda* were well documented by Best et al. (2003) from the southwest tip of Madagascar along the Madagascar Ridge to approximately 800 km south of Madagascar, where population abundance was estimated to be 424-472 in December 1996. This region is thought to be a summer feeding area for the population, and is also where the first example of the diagnostic song for the population was recorded (McDonald et al. 2006). The population migrates northwards through the Mozambique Channel, and likely up the east side of Madagascar as well, to suspected breeding areas from Kenya to the Seychelles. It is likely that *B. m. intermedia* at least migrate through these waters as well, as they have been acoustically documented in the southwest and northwest of Madagascar as described previously, and have been recorded to the southeast of Madagascar between February and August (Dréo et al. 2019). Kasuya and Wada (1996) describe extensive Japanese survey data associated with factory ship whaling fleets between 1965 and 1985, reporting sighting data on several species in 5° latitudinal by 5° longitudinal blocks to the south and east of Madagascar; they report *B. musculus* sightings just south of Madagascar (25°-30°S, 40°-50°E) on the northern Madagascar Ridge during December, corroborating the findings of Best et al. (2003).

During a large research vessel survey down the Madagascar Ridge to Walters Shoals south of Madagascar in 2017 (Campagne scientifique Walters Shoals MNHN-IRD, N/O Marion Dufresne; see <https://science4highseas.wixsite.com/waltersshoal>), there were no sightings of cetaceans during transit, but several species were documented in the Walters Shoals area in April-May (Gadenne and Saloma 2017). These included three groups of *B. physalus*, and given documentation of *B. physalus* song off the west coast of Madagascar, it is likely that the species also occurs in the Southern Madagascar Ecoregion, at least during migration periods. Kasuya and Wada (1996) report *B. physalus* sightings immediately south of Madagascar (25°-30°S, 45°-55°E) during December, likely on southern migration, but well south of 30°S from January to April in presumed feeding habitat.

The only reports of *B. borealis* (Sei Whale) near to Madagascar come from Kasuya and Wada (1996) who report some sightings just south of Madagascar (25°-30°S, 40°-45°E) during December, and much further south of 35°S between January and April. However, several other studies report no accounts of the species in Malagasy waters: during an extensive survey south and east of Madagascar, Gambell et al. (1974) report *B. borealis* only in the extreme east of the surveyed region, beyond 65°E; other large ship surveys in pelagic habitat report no *B. borealis* sightings (Dorémus et al. 2009; Gadenne and Saloma 2017; Ternon et al.



2018); and during long-term acoustic monitoring in the northern Mozambique Channel no diagnostic *B. borealis* vocalizations (e.g., paired down-sweeps) were recorded, despite an analysis protocol suitable for detecting them (Cerchio et al. 2018). Best (2007) states that the summer distribution of *B. borealis* is between the Subtropical Convergence and Antarctic Convergence (30°-40°S) and they migrate in winter to unknown temperate and tropical waters. Therefore it appears that *B. borealis* may occur in the vicinity of southern Madagascar, possibly during winter, but are rare and may be generally distributed further east and south.

Sightings of *B. edeni* (Bryde's Whale) were reported by Best (2001) over the Madagascar Ridge approximately 400 km south of Madagascar, and 105 were taken during Japanese whaling operations in the same area during 1977 (Ohsumi 1980). Best (2001) also surmises that 468 *B. edeni* taken by Soviet whalers in 1971 were likely taken off the southwest tip of Madagascar. Kasuya and Wada (1996) report *B. edeni* sightings just south of Madagascar (25°-30°S, 45°-50°E) from December through April. These are thought to be a distinct Madagascar population belonging to the subspecies *B. e. brydei* (Best 2007). Therefore the range of this species includes the offshore waters of southern Madagascar; however, it is noted that there are no modern confirmed observations of it nearer to the Madagascar coast. Previous anecdotal reports of *B. edeni* on the west coast (Rosenbaum 2003) are likely to have been of the similarly sized *B. omurai*, which was not described until 2003, or reported for Madagascar until 2015 (see Cerchio et al., 2022).

Minke whales (without species identification, but most likely *B. bonaerensis*) were reported in deep water roughly 100 km south of the Madagascar shelf during a large whale marking cruise (Gambell et al. 1974). Kasuya and Wada (1996) also report minke whales south of Madagascar (25°-30°S, 45°-55°E) during December (likely *B. bonaerensis*), and southwest of Madagascar (20°-30°S, 40°-45°E) during February. The latter group may represent *B. acutorostrata* "dwarf" ssp., as the majority of minke whale sightings during this period are distributed south of 50°S, and Kasuya and Wada (1996) state that many low latitude sightings may belong to the "diminutive form".

The southern Madagascar shelf is important breeding habitat for *Megaptera novaeangliae*, as satellite telemetry data indicated extensive use of this habitat during the height of the breeding season (Cerchio et al. 2016; Trudelle et al. 2016; Dulau et al. 2017). *Megaptera novaeangliae* were satellite tagged during a dedicated project in the southwest off Anakao during mid-season (July 2013), deliberately timed to assess habitat utilization by breeding whales; several whales demonstrated extensive movements over the southern Madagascar shelf, some making the transit from the southwest to the southeast coasts and back repeatedly during the duration of the tag (Cerchio et al. 2016). In particular, the southeast coast, south of Tolagnaro, was an area where males and to a lesser extent females lingered and displayed movement patterns consistent with breeding behavior (i.e., mate searching), both for whales tagged off Anakao (Cerchio et al. 2016) and whales tagged off La Réunion (during August 2013) which made the transit to Madagascar (Dulau et al. 2017). There is a single *E. australis* record off Tolagnaro reported in Rosenbaum et al. (2001).

**Odontocetes:** *Sousa plumbea* have been reported in the Deep

South near Cap Sainte Marie and on the southeast coast off Tolagnaro (M. Nicoll, as cited by Cerchio et al. 2015b). It is likely that this represents the extent of their range, which was proposed to be from the northwest along the entire western and southern coasts of Madagascar, but with no evidence along the east coast north of Tolagnaro (Cerchio et al. 2015b). *Tursiops aduncus* have been sighted off Tolagnaro (A. Saloma and F. X. Mayer, unpublished data), and are likely to occur throughout the southern coastal area. Dorémus et al. (2009), during a survey transiting over the continental slope south of Madagascar, sighted a large group of *Peponocephala electra* (approximately 200 individuals), *Stenella coeruleoalba* (with photographic documentation), and *Physeter macrocephalus* (including a group of seven individuals). Gambell et al. (1974) also report *S. coeruleoalba* within 100 km of the southern Madagascar shelf. Ternon et al. (2018) reported a group of approximately 30 *Globicephala macrorhynchus* off southern Madagascar during an expedition to the Madagascar Ridge. On a transit from the Madagascar shelf down the Madagascar Ridge, Gadenne and Saloma (2017) sighted five large groups of *T. truncatus* (estimated at up to 300 individuals).

Townsend (1935) reports historic catches of *P. macrocephalus* off Cap Sainte Marie and Tolagnaro concentrated north of latitude 27°S, Kasuya and Wada (1996) note concentrations of *P. macrocephalus* south of Madagascar (25°-30°S, 45°-55°E) from December to April, and Gadenne and Saloma (2017) sighted several *P. macrocephalus* in the vicinity of Walters Shoals. *Ziphius cavirostris* has been sighted within 200 km off the southwest corner of Madagascar (Best 2007). Macleod et al. (2006) report a sighting of *Mesoplodon mirus* (True's Beaked Whale; now considered *Mesoplodon eueu*, Ramari's Beaked Whale, Carroll et al 2021), in the vicinity of Walters Shoals at 33°S, 44°E; this is the only account of the species in southwest Indian Ocean region aside from strandings on the coast of South Africa, and although Walters Shoals is over 800 km from Madagascar, it is postulated that *M. eueu* ranges further north to southern Madagascar (Best 2007; Carroll et al 2021). Several other Ziphiidae species, including *Berardius arnuxii* (Arnoux's Beaked Whale), *Tasmacetus shepherdi* (Shepherd's Beaked Whale), *Hyperoodon planifrons* (Southern Bottlenose Whale), *Mesoplodon hectori* (Hector's Beaked Whale), *M. grayi* (Gray's Beaked Whale), *M. bowdoini* (Andrew's Beaked Whale), and *M. layardii* (Strap-toothed Beaked Whale), have circumpolar or southern Indian Ocean distributions, and have either been sighted or are postulated to occur over the Madagascar Ridge, but are not here considered to occur around Madagascar, as they are generally considered to be cold or cold-temperate species with no evidence of ranging within Madagascar waters (Best 2007).

#### THE EAST MADAGASCAR MARINE ECOREGION (INCLUDING THE EAST COAST OF NORTHERN MADAGASCAR)

The East Madagascar Marine Ecoregion includes the entire east coast of Madagascar from just north of Tolagnaro to Cap d'Ambre, an approximately 1500 km length of coastline. (Of note is that the ecoregion as defined by Obura et al (2012) and adopted in the Madagascar National Parks strategic plan places the most northeastern coast of Madagascar, approximately 500 km from the Masoala Peninsula to Cap d'Ambre, into the Northern

Mozambique Channel Ecoregion. In the present contribution we prefer to treat the northeast coast of Madagascar within the Eastern Madagascar Ecoregion for purposes of describing cetacean diversity). The eastern coast of Madagascar is characterized by a relatively narrow continental shelf and a steep slope to abyssal plane depths and oceanic habitat. The shelf widens to a maximum of 60 km for an approximately 250 km stretch from the south end of the Masoala Peninsula to just north of Toamasina, but it is typically no more than 10 km wide aside from that region. The area of broader shelf includes Antongil Bay (approximately 60 km long by 30 km wide), Ile Sainte Marie, and the Sainte Marie Channel, two areas where extensive research has been conducted on the Southwest Indian Ocean population of *Megaptera novaeangliae* (Rosenbaum et al. 1997; Cerchio et al. 2016; Trudelle et al. 2018), but where there is relatively low cetacean species diversity. Aside from work on *M. novaeangliae*, a section of the REMMOA surveys in 2009 were conducted from Ile Sainte Marie extending offshore to Tromelin Island. The work to date has revealed a modest species diversity compared to the other regions of Madagascar with a total of 14 confirmed species, including two Mysticetes and 12 Odontocetes, and an additional eight species likely to occur and six species possibly to occur in the area (Table 7-16).

### Cetaceans in the East Madagascar Marine Ecoregion

**Mysticetes:** Branch et al. (2007) report scattered historic (prior to 1973) whaling catches of *Balaenoptera musculus* off the east coast of Madagascar, and a single modern anecdotal sighting in November. It is not clear whether these represent *B. m. intermedia* or *B. m. brevicauda*; however, given evidence off west Madagascar it seems likely that both subspecies are present. Best (2001) proposes that a Madagascar population of *B. edeni* migrates from the Madagascar Ridge in the south, up the east coast of Madagascar to the Seychelles; however, aside from reports of sightings by Japanese whalers in pelagic waters between 50° and 70°E (Ohsumi 1980), there are no confirmed modern accounts of *B. edeni* off the eastern coast of Madagascar.

The southwest Indian Ocean breeding population of *Megaptera novaeangliae* has been studied extensively in the Antongil Bay and Ile Sainte Marie region. The area was first considered the primary breeding ground and destination within Madagascar (Rosenbaum et al. 1997; Ersts and Rosenbaum 2003), before aggregations were recognized off other parts of Madagascar. Photographic capture-recapture of individuals within Antongil Bay from 2000 to 2006 revealed very short residency periods and it was postulated that there was a constant flow of individuals in and out of the bay (Cerchio et al. 2009b). Moreover, abundance was estimated at 5000-8000 individuals, and it was recognized that sampling in Antongil Bay was occurring of a very large population in only a fraction of its range. Despite a low capture probability, most individuals that were recaptured between years arrived each year within a few days on the Julian calendar, representing a highly consistent periodicity in migratory timing congruent with a population moving through the area with a defined movement pattern (Cerchio et al. 2009b).

Photographic recapture studies of *M. novaeangliae* between 1997 and 2006 indicated across-year recaptures of individuals

between Antongil Bay and Mayotte or east Africa (Cerchio et al. 2008; Ersts et al. 2011), and satellite telemetry studies in 2011 revealed that some animals tagged off Ile Sainte Marie were moving through the region migrating to the east African coast (Cerchio et al. 2016; Trudelle et al. 2016). Individuals tagged off Ile Sainte Marie and off La Reunion in 2011-2012 also revealed near constant movement around Madagascar, and preferred breeding habitat appeared to be in the south Sainte Marie Channel and on the shelf of central Madagascar in the vicinity of Toamasina, with no movement into Antongil Bay (Cerchio et al. 2016; Dulau et al. 2017). Females with calves tend to prefer shallower near-shore habitat (generally <30 m) in both Antongil Bay and the Sainte Marie Channel, despite the uniformly shallow and poorly contrasting bathymetry (generally <70 m) of both regions (Ersts and Rosenbaum 2003; Trudelle et al. 2018); however, satellite telemetry studies indicate that females with calves also make extensive movements in deep oceanic water, and active breeding habitat for females (with and without calves) extend into deeper shelf waters (to 200 m) (Cerchio et al. 2016; Trudelle et al. 2016).

*Eubalaena australis* have been sighted infrequently but regularly on the east coast of Madagascar, including initially two published sightings, an adult in Antongil Bay in July 1997, and a mother with a calf off Tolagnaro in November 1999 (Rosenbaum et al. 2001). Since then there have been sightings in Sainte Marie Channel of an additional six groups during July-August in 2013, 2015, 2016, and 2018, including four different mother-calf pairs, one pair of adults, and one solitary adult (A. Saloma and F. X. Mayer, unpublished data). These combined with three previous mentioned accounts in the southwest (Anakao and Ifaty, including an additional mother-calf pair in 2010) suggest that *E. australis* are regular visitors to Madagascar, and the hypothesis that these may represent a remnant population that was heavily exploited in feeding grounds in the Crozet Islands should be revisited (Rosenbaum et al. 2001). The preponderance of mother-calf pairs in these sightings (five of nine documented groups) raises the possibility that females may be calving in these waters. The size of observed calves off Ile Sainte Marie were in all cases considered small enough to be neonates, likely born in Madagascar waters; in addition in all but one case the mother-calf pairs lingered in the area, sighted on multiple successive periods ranging from 2 to 10 days (A. Saloma and F. X. Mayer, unpublished data).

**Odontocetes:** *Tursiops aduncus* were frequently encountered in Antongil Bay and the Sainte Marie Channel (S. Cerchio and N. Andrianarivelo, unpublished data; A. Saloma and F. X. Mayer, unpublished data), and appear to be the most commonly sighted coastal dolphin in the area. *Stenella longirostris* were sighted at least once in the mouth of Antongil Bay (S. Cerchio and N. Andrianarivelo, unpublished data), but have never been confirmed around Ile Sainte Marie during extensive effort on ecotourism boats (A. Saloma and F. X. Mayer, unpublished data). Therefore, they appear to be less common in at least this area compared to the northwest and southwest coasts, although there are several reports of the species further north between Cap Est and Antalaha (A. Cooke, unpublished data). *Stenella coeruleoalba* were potentially encountered once off Ile Sainte Marie, and there was a confirmed stranding on the east coast of that island (A. Saloma

and F. X. Mayer, unpublished data), so they appear to occur but like *S. longirostris* are infrequently sighted. In total, these three Odontocetes species represent a low diversity in the shallow waters of Antongil Bay and Sainte Marie Channel. *Stenella coeruleoalba* were also reported in deep water 100 km offshore the central east coast (Gambell et al. 1974), suggesting that *Stenella* spp. are more common offshore.

The northeast coast of Madagascar (about 100 km north and south of Ile Sainte Marie) offshore to Tromelin Island was surveyed in January 2010 by REMMOA aerial surveys (Van Canneyt et al. 2010). During this survey the presence of at least 10 species of Odontocetes was confirmed. Relatively low density of small Delphininae (likely *Stenella* spp.) were encountered with 0.4 individuals per 100 km<sup>2</sup> estimated for this survey block (Laran et al. 2017), the lowest value of the SWIO REMMOA survey, congruent with data from small-boat surveys mentioned above. *Stenella attenuata* was the only small Delphininae identified at the species level. Large Delphininae with *T. truncatus* and one group of 200 *Lagenodelphis hosei* were encountered in addition to *Tursiops* spp. Their global density was also the lowest estimated for the region, equivalent to that in Mauritian waters with 2.4 individuals per 100 km<sup>2</sup>. Large groups of *Peponocephalus electra* (up to 200 individuals) were the most abundant species in this surveyed area, with a global density of small Globicephalinae estimated to 9.3 individuals per 100 km<sup>2</sup>. This species has a strong preference for the slope habitat with 80% of the sightings encountered at less than 30 km from the 2000 m isobath contours. Several sightings of *Pseudorca crassidens* and one *Globiocephala macrorhynchus* were identified off shore, between Tromelin and the Malagasy coast. Density of large Globicephalinae was estimated to 0.7 individuals per 100 km<sup>2</sup>, an intermediate value for the region.

No *Grampus griseus* were identified in the area, although previously there is a single account reported 230 km off the east coast at 20.7°S (Gambell et al. 1974). Only one sighting of a *Kogia* sp. was reported between the Mascarene Archipelago and the Malagasy coast, with species identification ambiguous. Among Ziphiidae, *Z. cavirostris* and *Indopacetus pacificus* were identified along the eastern slope (Van Canneyt et al. 2010), and there is a tentative sighting of *Mesoplodon ginkgodens* (Ginkgo-toothed Beaked Whale) far off eastern Madagascar, a species which is postulated to range throughout the region (Ballance and Pitman 1998; Best 2007). Density of Ziphiidae as a species group was estimated to an intermediate value of 0.2 individuals per 100 km<sup>2</sup> (Laran et al. 2017). Finally, *Physeter macrocephalus* were encountered along the Malagasy slope and offshore, in groups up to four individuals (although, a likely underestimate of group size) and with a relative density of 0.09 individuals per 100 km<sup>2</sup>; this is equivalent to the estimated density for the Seychelles, the highest density for the species throughout the Southwest Indian Ocean (Laran et al. 2017), and among the higher estimates for all tropical areas surveyed by the REMMOA project (including the West Indies, French Guiana, French Polynesia, New Caledonia, and Wallis and Futuna). In addition, there have been two stranded *P. macrocephalus* on Ile Sainte Marie, including a 10 m juvenile in 2012 and a nearly 20 m adult male in 2018 (A. Saloma and F. X. Mayer, unpublished data). Therefore, this region is clearly important habitat for this species, including use by large bulls.

## THREATS AND CONSERVATION

Several threats to cetaceans have been identified in Madagascar's waters. Much of the coastline of Madagascar is remote and undeveloped although there are several developed and heavily populated centers, including the port cities of Mahajanga, Toliara, Tolagnaro, and Toamasina, and the tourism hubs around Nosy Be, Antsiranana, and Ile Sainte Marie. Hunting and bycatch of small cetaceans has been documented in coastal small-scale fisheries (Figures 7-29A and 7-29B), and although hunting is most prevalent in the southwest region, it not entirely absent on the northwest and east coasts (Cerchio et al. 2014, 2015b). Coastal industrial fisheries (in the form of shrimp trawling) and offshore industrial fisheries (tuna purse-seine and long-line) may also impact cetaceans (IOTC 2019). Currently there is extensive offshore petroleum exploration (Figure 7-29C) planned at least in the northwest region, which presents a distinct threat to sensitive coastal populations of cetaceans (Cerchio et al. 2014, 2019). Noise from large ships also impacts baleen whales by interfering with vocal communication (Cholewiak et al. 2018), and there are major shipping lanes through the Southern Madagascar Ecoregion, as well as in the western Mozambique Channel (Figure 7-29D) (Vespe et al. 2015). The large volume of shipping traffic also presents the potential for lethal ship strikes of large whales, particularly around ports and when shipping lanes overlap with migration routes as they do south of Madagascar.

There is also coastal industrial development in the form of proposed or active mining operations to the south of Nosy Be (proposed rare earth mining on the Ampasindava Peninsula), Tolagnaro (coastal mining of ilmenite sands), and Toamasina (nickel ore processing plant), which have the potential to pollute coastal waters. Marine pollution in the form of litter and debris was assessed during the REMMOA aerial surveys with a maximum encounter rate of marine litter around Comoros Archipelago, as well as along the northwest and northeast coasts of Madagascar (Laran et al. 2017); included among marine debris are “ghost nets”, discarded or lost drift nets, that continue to bycatch marine megafauna and pose a substantial threat to pelagic cetaceans (Anderson et al. 2020). Finally, climate change is an overarching threat for cetaceans on a global scale, through multiple direct and indirect impacts that are poorly understood but could have broad effects on abundance, distribution, migration, feeding ecology, reproductive ecology and survival (Simmons and Elliott 2009). Certain populations may be particularly vulnerable, such as resident populations with limited habitat, or populations that are dependent on sea ice and polar productivity cycles. Potential indirect impacts on resident populations around Madagascar could occur through changes in rain fall, ocean circulation patterns and primary productivity. Similarly, migratory species of baleen whales rely on Antarctic productivity cycles for seasonal feeding; as rapid changes in the Antarctic continue to progress these resources may come under increasing stress. For both these resident and migratory species, these changes could perturb the ecosystem and availability of food resources, thus in turn resulting in distribution shifts or potentially collapse of cetacean populations.

Focusing on a few of the most imminent threats to Madagascar cetaceans, possibly the most currently impactful is directed hunting and incidental bycatch of coastal dolphins in small-scale

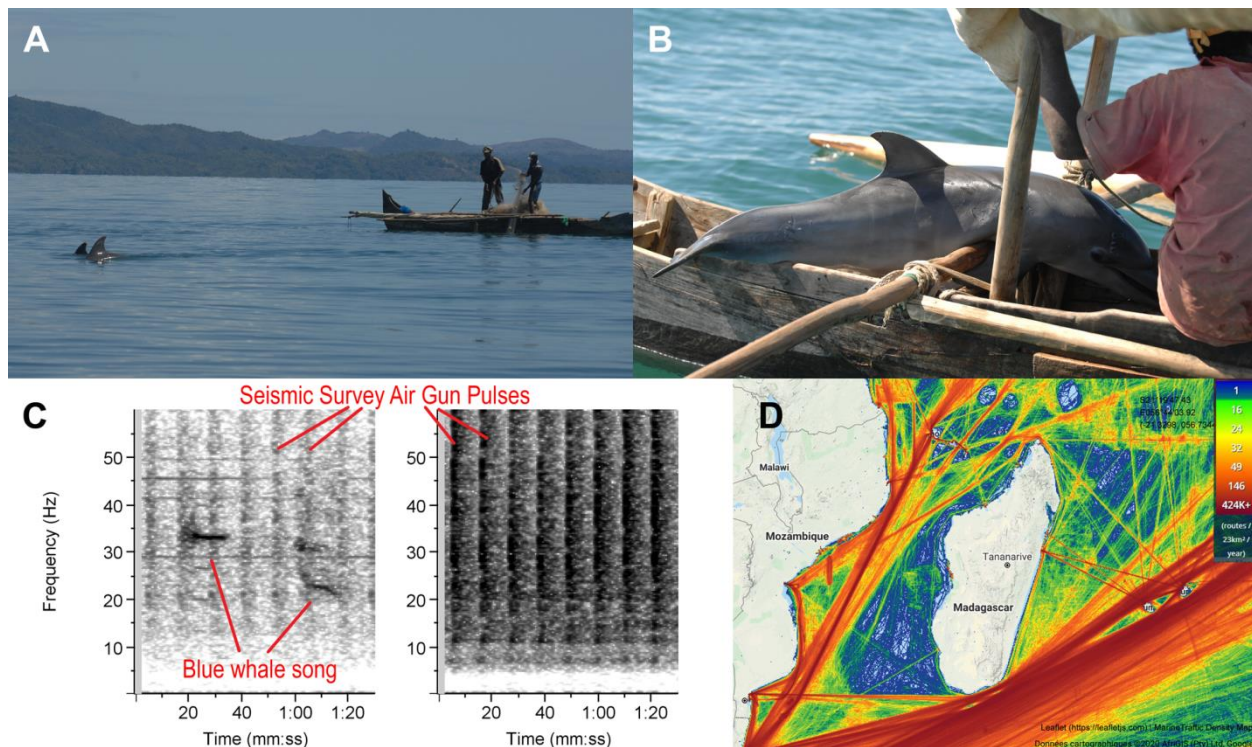


Figure 7-29. Examples of threats to cetaceans in Malagasy waters: A) small-scale fisheries and use of gill nets by Malagasy fishers from Nosy Faly, off the east side of Nosy Be; B) bycatch of juvenile *Tursiops aduncus* by small-scale fishers in same event as illustrated in A; observations over several weeks and discussions with these fishers suggested that they may be setting their nets deliberately in areas where dolphins foraged, with the knowledge that dolphins may become entangled when attempting to depredate their nets. Thus this behavior may be a form of “directed bycatch” and a step towards directed hunting that is common in other regions (e.g., the southwest) but rare in Nosy Be; C) acoustic interference of seismic survey air gun pulses as illustrated by sound spectrographs (graphic representation of sound with time on the x-axis, and frequency or pitch on the y-axis) of *Balaenoptera musculus breviceauda* song with a distant seismic survey in the background (left), and a much closer seismic survey (right) that would completely mask a *B. musculus* song; and D) density of shipping traffic around Madagascar as illustrated for 2017 in routes / 23 km<sup>2</sup> / year, showing the major shipping lane south of Madagascar and to a lesser extent to the west of Madagascar. (PHOTO A by N. Andrianarivelo and B by S. Cerchio) (SOURCES: C from recordings off Nosy Be, Madagascar, S. Cerchio, unpublished data; D from Marine Traffic <https://www.marinetraffic.com/>)

and artisanal fisheries (Andrianarivelo 2001; Razafindrakoto et al. 2004, 2008; Cerchio et al. 2009a, 2014, 2015b). Active hunting by Vezo fishers on small coastal cetaceans, including primarily *Sousa plumbea*, *Tursiops aduncus*, and *Stenella longirostris*, was first documented in the Anakao region, where an estimated 7000 individuals were taken between 1985 and 2000, primarily in drive hunts where an entire pod of dolphins is killed in a single event (Andrianarivelo 2001). The hunting tradition was later found to be widespread in the southwest, based on affirmative reports in interviews from 10 of 11 surveyed localities encompassing 22 villages between the Barren Islands and Toliara (Cerchio et al. 2015b). This hunting tradition does not occur in the northwest of Madagascar, where the Sakalava people have a taboo (*fady*) on the hunting and eating of dolphins; however, incidental bycatch and some low level hunting has been documented off Nosy Be (Figures 7-29A and 7-29B) (Cerchio et al. 2014, 2015b). Based upon sighting data, interviews, and direct observation of mortality,

*Sousa plumbea* in the Anakao area appear to be heavily impacted by this artisanal hunting and bycatch, with evidence of a decline in encounter rates and group size from 1999 to 2013. It is believed that this hunting pressure is unsustainable and may be leading to the extirpation of these southwest coastal populations. The northwest coast appears to be a haven for *S. plumbea* relative to much of the other parts of their range in Madagascar waters, as the species is frequently sighted around the Nosy Be region.

In the southwest, conservation efforts have involved engaging hunting communities to create community-based organizations for the conservation of cetaceans, implementation of traditional laws (*dina*) governing cetacean takes, education and awareness raising campaigns, and development of alternative livelihoods (community-based ecotourism). These efforts have been successful in the Anakao region with the creation of the locally-managed *Fikambanana Miaro ny Trozona sy Fesotra* (FMTF, Association for the Protection of Whales and Dolphins) in 2007,

followed by the ratification of a 24-article *dina* governing the protection of marine mammals and regulating community-based whale watching. Yearly training in responsible whale-watching practices for local eco-guides and boat operators has been conducted since the creation of the FMTF by the Institut Halieutique et des Sciences Marines. These efforts have resulted in a reported cessation of the primary hunting effort since 2009 and rise of a local Malagasy whale watching industry (Cerchio et al. 2014; N. Andrianarivelo, unpublished data). The same conservation model was initiated in the Befandefa Commune (villages in the vicinity of Andavadoake) where substantial hunting was reported particularly from the village of Bevohitse; the initial response of the villages was promising with the creation of locally-managed associations and drafting of *dina* in four distinct locales (Cerchio et al. 2014), but the program was abruptly ended before completion in 2015, when the NGO supporting the work shifted priorities. As a consequence the fishers resumed hunting with documented drive hunts on approximately 100 *Stenella longirostris* off Bevohitse in 2016, and 30-40 *Grampus griseus* off Salary Bay (in the Soariake Marine Protected Area) in June 2018 (T. Collins, unpublished data). These events emphasize the importance of following through with conservation actions for effective conservation to endure.

Aside from targeted small-scale fishery interactions that have been documented, industrial fisheries involving both national and international fleets likely impact cetacean populations in the Malagasy EEZ but remain poorly documented. The main industrial fisheries in Madagascar waters include a national fleet of 78 trawlers and longline vessels operating over the continental shelf targeting shrimp, fish or tuna, and a foreign fleet of 168 purse-seine and longline vessels operating mainly beyond the continental shelf targeting tuna and tuna-like fishes (see Cooke et al., 2022). However, there are virtually no data on the interactions of these fisheries with cetaceans in Madagascar's waters. There is some evidence for bycatch of cetaceans in industrial tuna purse-seine fisheries in the Western Indian Ocean (Ruiz et al. 2018), but it remains unquantified for the Malagasy EEZ. Industrial tuna purse-seining operations elsewhere in the Western Indian Ocean have been reported to be sometimes associated with baleen whales, but fatal or harmful interactions appear rare. In one study based on 494 sets, 45 were associated with baleen whales primarily in the central equatorial Indian Ocean (outside of Malagasy waters), and notably with one fatality by entanglement of a baleen whale (Romanov 2002). Impacts of longline fisheries on cetaceans in the Indian Ocean have not been well-documented but observer presence on board vessels is also very low (IOTC 2008), which could account for the lack of information. More recently IOTC longline fisheries have reported interactions with marine mammals in eastern and southern Malagasy waters, primarily involving *G. griseus* (IOTC 2019). Commercial gillnet (driftnet) tuna fisheries have been reported to have a critical impact on cetaceans throughout the Indian Ocean through bycatch over the past half-century or more, but there are no reports of such fishing in Madagascar waters (Anderson et al. 2020). To conclude, more research is required to evaluate the impact on cetaceans of national and foreign commercial fisheries in Malagasy waters.

Oil and gas exploration utilizes intense sound sources for acoustically imaging the ocean floor and crust; these include high

intensity sonar at mid to high frequencies for detailed mapping of bathymetry, and geophysical seismic surveys that use low frequency airguns for the acoustic imaging of substrata beneath the seabed (Figure 7-29C). These loud anthropogenic noises pose threats to cetaceans, including the potential for physical damage if in close proximity, disturbance of behavior, and interference with cetacean vocal communication (Nowacek et al. 2007; Clark et al. 2009; Cholewiak et al. 2018). Petroleum exploration has occurred off the coasts of Madagascar since at least 2005, and potential impacts on cetaceans have been documented on the northwest coast in particular. In May 2008, 100-200 *Peponocephala electra* entered the extensive Loza Lagoon system, with numerous strandings recorded as far inland as the town of Antsohihy. Upon reviewing all available information related to the mass stranding, an Independent Scientific Review Panel concluded that the most likely cause was a behavioral startle response to Multi-beam Echosounder bathymetric profiling that was being conducted on the continental slope prior to the commencement of geophysical seismic exploration for offshore petroleum reserves (Collins et al. 2009; Southall et al. 2013). Recent passive acoustic monitoring off Nosy Be documented the daily presence of seismic airguns for seven months from mid-October 2017 to late May 2018 (S. Cerchio and T. Rasoloarijao, unpublished data). These seismic surveys coincided with the southern migration of *Balaenoptera musculus brevicauda* through the eastern Mozambique Channel, and at times were intense enough to mask the songs of the migrating whales (Figure 7-29C). Continued seismic surveys are planned in the region starting as soon as 2021, overlapping with breeding habitat of Critically Endangered *B. m. intermedia*, among the other sensitive baleen whale populations that range in the Mozambique Channel.

The boundaries of several Madagascar Marine Protected Areas overlap with the ranges of many of the cetaceans reported on here (see Cooke et al., 2022). Some of these were developed taking into consideration cetacean distribution patterns. In the northwest, the boundaries of the Ankarea protected seascape (135,556 ha, decree 2015-721) and Ankivonjy protected seascape (139,410 ha, decree 2015-722) were created specifically in response to the cetacean diversity surveys in the Nosy Be region (S. Cerchio et al., unpublished data). During 2019, the IUCN Marine Mammal Protected Areas Task Force convened a workshop of international marine mammal experts to identify Important Marine Mammal Areas (IMMAs) in the western Indian Ocean and Arabian Sea (IUCN-MMPATF 2019; Notarbartolo di Sciara and Hoyt 2020). In Madagascar waters, eight distinct candidate IMMAs were identified as 'discrete habitat areas, important for one or more marine mammal species, that have the potential to be delineated and managed for conservation' (IUCN-MMPATF 2019). Six of these candidates have already been considered as IMMA, largely aligning with the marine ecoregions (IUCN-MMPATF 2020; see Cooke et al., 2022). These include: the Northwest Madagascar and Northeast Mozambique Channel IMMA (120,614 km<sup>2</sup>); the Southwest of Madagascar and Mozambique Channel IMMA (139,494 km<sup>2</sup>); the Toliara, Saint Augustin Canyon and Anakao, Madagascar IMMA (6069 km<sup>2</sup>); the Southern Madagascar IMMA (18,575 km<sup>2</sup>); and the Madagascar Central East Coast IMMA (55,524 km<sup>2</sup>). Still pending final decisions are the Central Mozambique Channel candidate IMMA, and the Madagascar Ridge candidate IMMA. Recognized by international experts as

## MARINE AND COASTAL ECOSYSTEMS

important habitat for marine mammals according to a rigorous and standardized set of criteria, these IMMAs do not carry any governance or protected status with respect to Malagasy legislation; rather they serve “to attract the attention of policy- and decision-makers to the opportunity or need to ensure the favorable conservation status of marine mammals in that specific area

through the implementation of the most appropriate management measures”. As such, it is strongly recommended that the Malagasy authorities and conservation NGOs take into consideration the findings of the MMPATF IMMA committee in fisheries management and marine conservation planning in order to help protect Madagascar’s rich cetacean fauna.

Subject editors: Andrew Cooke and Steven M. Goodman

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