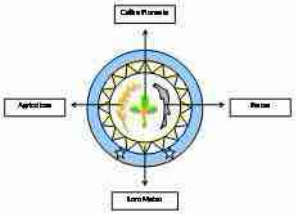
Marine Megafauna Surveys in Timor Leste: Identifying Opportunities for Potential Ecotourism— Final Report




Project 3 - The Timor-Leste Coastal / Marine Habitat Mapping for Tourism & Fisheries Development Project

June 2009

Australian Government

Australian Institute of Marine Science

Northern Territory Government

Marine megafauna surveys in Timor Leste: identifying opportunities for potential ecotourism – Final Report

Date: June 2009

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Kiki Dethmers (NRETAS), Ray Chatto (NRETAS), Mark Meekan (AIMS), Anselmo Lopes Amaral (MAF-Fisheries), Celestino Barreto de Cunha (MAF-Fisheries), Narciso Almeida de Carvalho (MAF-Fisheries), Karen Edyvane (NRETAS).

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Executive Summary

Aims and methods

- The aim of this study was to determine if cetaceans and other megafauna aggregated in the nearshore waters of Timor Leste, and if so, to assess opportunities for regional ecotourism industries based on this resource.
- The project included (i) monthly aerial surveys (ii) field ground-truthing using boats and (iii) training of TL government staff in aerial survey techniques (manual prepared) and GIS analysis of data.
- A light plane was used for aerial surveys of megafauna within two nautical miles of the coastline on a monthly basis from April to November 2008. During four days in November megafauna were also surveyed using a boat along the Dili region of the coast.

Main findings of aerial and boat surveys

- Dolphins and small whales were sighted throughout all of Timor Leste's coastal waters and throughout the entire survey period from April – November
- The majority of sightings occurred along the north coast and mostly west of Baucau
- Large whales were observed frequently along the north coast and were mostly identified as blue whales (*Balaenoptera musculus*). A single sperm whale (*Physeter macrocephalus*) was sighted on the south-eastern coast and a mother and calf Bryde's whale (*Balaenoptera brydei*) or possibly sei whale (*Balaenoptera borealis*) in the north-east
- A total of three whale sharks (*Rhincodon typus*) were observed and all were small (<5 m) individuals
- The diversity and abundance of cetaceans peaked during November when very large pods (several hundreds of animals) were observed both along the north and the south coasts
- Abundances of large turtles also increased in nearshore waters during the November, especially in the Nino Konis Santana Marine Park region
- A total of 13 different cetaceans were identified, including the blue whale, sperm whale, Bryde's or sei whale, short-finned pilot whale (*Globicephala macrorphyncus*), false killer whale (*Pseudorca crassidens),* pygmy killer whale (*Feresa attenuata*), melon-headed whale (*Peponocephala electra*), Cuvier's beaked whale (*Ziphius cavirostris*) , Risso's dolphin (*Grampus griseus*), Fraser's dolphin (*Lagenodelphis hosei*), spotted dolphin (*Stenella attenuata*), rough-toothed dolphin (*Steno bredanensis*), and the spinner dolphin (*Stenella longirostris*).

- The near-shore coastal waters of Timor Leste are characterized by an exceptional diversity and abundance of cetaceans. This resource provides a significant opportunity for development of ecotourism involving whale and dolphin watching, particularly along the north coast of Timor Leste.

Capacity-Building and TL Engagement

- Training of Timor Leste Government staff in aerial survey techniques (manual prepared).

Emerging Issues & Priorities

- Aerial surveys in combination with boat-based and acoustic studies are required to build on the current information on species diversity, abundance and distribution and to identify behavioural activities and patterns, particularly around the time of November.
- Tagging studies using satellite telemetry and/or genetic fingerprinting are required to define migratory pathways, identify populations and connectivity.
- Oceanographic and trophic studies in the Wetar – Ombai Strait to identify key seasonal and localized upwellings, primary and secondary productivity, and potential key prey species of cetaceans.
- Surveys of traditional ecological knowledge are required to complement aerial and boat survey data.
- Training and capacity building on survey techniques, species identification, marine megafauna biology and conservation.
- Capacity building for community-based whale- and dolphin-watching ventures
- Development of cetacean watching policies, guidelines, regulations and compliance
- Identification of threats to megafauna in Timor Leste waters
- Government policies for deep-sea and shallow-water cetacean habitat protection and threatened species management.

Sumáriu

Objetivu no métodu sira

- Objetivu prinsipál estudu ne'e nian mak atu determina se *cetácio* (cetacean) no megafauna sira seluk konsentra iha tasi ninin Timor-Leste nian, se nune'e karik, atu tetu oportunidade hodi dezenvolve indústria eko-turizmu ne'ebé bazeia ba rekursu ida-ne'e.
- Projetu ne'e inklui (i) levantamentu aéreu fulan-fulan (ii) uza ró atu hare tuir iha terrenu (iii) treinu ofisiál Governu nian iha téknika levantamentu aéreu (moos prepara livru ida kona-ba formasaun ne'e) no moos análize informasaun sistema informasaun jeográfika.
- Levantamentu aéreu ne'e Hala'o ho aviaun ki'ik no kmaan iha distánsia milla nautika rua dook husi tasi ninin fulan-fulan. Hahú levantamentu iha fulan Abril no hala'o to'o fulan Novembru 2008. Durante loron 4 iha Novembru levantamentu megafauna la'o tuir ró iha rejiaun Dili.

Rezultadu prinsipál husi foti dadu aéreu no tuir ró

- Durante tempu peskiza nian, entre Abríl to'o Novembru, haree-hetan ikan-lemur (Toniñu) no Uud (baleia) ki'ik oan sira iha kosta Timor-Leste tomak
- Maioria rezultadu haree hetan mai husi tasi feto (Kosta norte) liu-liu Baucau osidentál.
- Baleia ne'ebé haree maioria adultu sira, no sira nani fali iha tasi feto no maioria sira mak *Balaenoptera musculus.* Durante levantamentu ema moos hetan *Physeter macrocephalus* ida iha zona oriental tasi mane no inan no oan ida husi *Balaenoptera brydei* ka *Balaenoptera borealis* karik iha nordeste.
- Durante levantamentu ema hetan total tubaraun-baleia tolu, no sira hotu ki'ik (ki'ik liu metru 5)
- Setáceo sira nia diversidade no númeru sa'e durante fulan Novembru bainhira haree-hetan balada ne'e atus-ba-atus iha kosta- norte no kosta-sul.
- Levantamentu moos hetan katak durante Novembru númeru lenuk-boot sai, liuliu iha área Parke Mariñu Nino Konis Santana.
- Durante levantamentu ne'e ema hetan espésie setaseo sanulu resin tolu ne'ebé inklui blue whale, sperm whale, Bryde's or sei whale, short-finned pilot whale (*Globicephala macrorphyncus*), false killer whale (*Pseudorca crassidens),* pygmy killer whale (*Feresa attenuata*), melon-headed whale (*Peponocephala electra*), Cuvier's beaked whale (*Ziphius cavirostris*) , Risso's dolphin (*Grampus griseus*), Fraser's dolphin (*Lagenodelphis hosei*), spotted dolphin (*Stenella attenuata*), rough-toothed dolphin (*Steno bredanensis*), and the spinner dolphin (*Stenella longirostris*).

- Timor-Leste nia tasi laran hetan diversidade no abundánsia *setáceo* makás liu. Rekursu ida-ne'e oferese oportunidade boot ida ba dezenvolvimentu eko-turizmu (ezemplu, programa atu haree baleia no golfiñu sira), liuliu iha parte kosta norte Timor-Leste nian.

Kapasitasaun no Partisipasaun TL nian

- Treinu ba funsionáriu sira Governu Timor-Leste nian kona-ba téknika peskiza aéreu (manuál kona-ba ida ne'e prepara tiha ona).

Problema no Prioridade ne'ebé foin sa'e

- Presiza halo peskiza aéreu tan hamutuk ho levantamentu ho métodu akustiku hodi hasa'e informasaun kona-ba diversidade, abundansia no distribuisaun no moos identifika komportamentu no padraun sira liu-liu iha fulan Novembru.
- Uza markadór telemetriku/jenétiku atu peskiza, lehat no identifika rota migrasaun no identifika orijen no ligasaun populasaun sira.
- Estudu *oseanográfico* no kona-ba katuir-*trofiku* iha Estreitu Wetar – Ombai atu identifika zona *upwelling* (tasi-bokur) bainhira mak zona bokur no iha ne'ebé loloos mak bokur, produtividade-primária no sekundária, no potensialidade kona-ba *espésie setáneo* importante.
- Presiza hala'o levantamentu kona-ba matenek ekolójiku tradisionál hodi hasa'e dadu sira husi levantamentu aereo no tuir ró.
- Treinu no kapasitasaun kona-ba téknika foti dadu (levantamentu), tada (rekoñese) espésie, no biolojia no konservasaun.
- Identifikasaun, avaliasaun no análize komunitária (community-based), lenuk no vijilánsia ba *setáneo* iha Timor-Leste.
- Dezenvolvimentu ba programa, matadalan, regulamentu no kumprimentu ba ema ne'ebé hakarak haree *setáneo* (cetacean watching).
- Identifika ameasa ba megafauna (balada boboot sira) iha Timor-Leste nia tasi laran.
- Polítika governu nian kona-ba protesaun ba *setáneo* ninia habitat iha tasi-kle'an no tasi-badak no jestaun ba animál sira ne'ebé hetan ameasa.

Introduction

Over the last 20 years, ecotourism to view and interact with marine megafauna has become increasingly popular. Examples of this type of tourism include whale watching, cage diving with white sharks and snorkelling with whale sharks. The economic value of these industries is now immense. Whale watching trips are available in more than 87 countries around the world and in 2000 involved 9 m participants generating an income to whale-watcher operators and supporting infrastructure (such as accommodation, restaurants and souvenirs) of over one billion dollars (Hoyt 2001). This revenue increased 5 fold over the decade of the 1990's (Hoyt 2001). Moreover, since many of the megafauna aggregations occur in regional areas remote from centres of population, such tourism provides significant flow-on effects to local economies where few alternative sources of income exist. It is also notable that this industry has not been limited to developed countries. Many of the fastest-growing industries are located in small Pacific Island countries that have only very limited infrastructure and tourism facilities, such as Papua New Guinea, the Solomon Islands, Tonga, Samoa and the Federated States of Micronesia.

The ocean current systems that surround Timor Leste are well known as a migration pathway for many species of marine megafauna including cetaceans, sharks and other fishes (Kahn 2005). Megafauna assemblages are very diverse, with over a third of all known whale and dolphin species found in the region. Additionally, other types of megafauna such as whale sharks (*Rhincodon typus*) and manta rays (*Manta birostris*) are also known to inhabit the region. Whale sharks, orcas (*Orcinus orca*) and mantas have been sighted at Whale Shark Point (also known as Lone Tree) during the months of August-November, and groups of migrating whales and dolphins are regularly seen in the deep waters between Dili coastline and Ataúro Island. The approach of megafauna close to the coast of Timor is facilitated by the very deep (3km) waters just offshore and the narrow fringing reef lining the coast. Indeed, this ease of access is testified by the tradition of hunting these

animals using small boats by some Indonesian communities on nearby islands (Reeves 2002, Lundberg 2003).

If aggregation sites of megafauna can be identified within access of the shore of Timor Leste then this may provide an opportunity for the development of a regional industry based on ecotourism. Ningaloo Reef in Western Australia shows an example, and the potential value, of such an industry. At Ningaloo, whale sharks are encountered close to the fringing reef where tourists can snorkel with the animals. Over a season of 3-4 months this tourism generates in the order of $20m for the Ningaloo region and has acted as a drawcard that has facilitated the development other related industries such as turtle and whale watching.

The simplest and most efficient means to locate marine megafauna is by aerial survey. Given that megafauna sighted in Timor Leste waters are likely to be migratory rather than resident animals, it is necessary to spread the sampling of megafauna throughout a year. Regular aerial surveys of the coastal waters of Timor Leste using a light plane were conducted between April and November 2008. The main objective of these surveys was to quantify distribution and abundance patterns of marine megafauna. A 4-day survey on board of a research vessel was done to ground-truth observations made during the aerial surveys and to obtain species identifications.

Methods

Aerial surveys

Between April and November 2008 aerial surveys were conducted of marine megafauna in the waters adjacent to the Timor Leste coast to establish a baseline description of biodiversity, abundance and the identification of possible marine megafauna “hot-spots” in the region. A total of 7 surveys were made at roughly 1-month intervals, depending on weather and aircraft availability. All surveys used a single engine over-head wing Airvan aircraft provided by the Mission Aviation Foundation (Fig. 1a). The survey teams were composed of two or three observers positioned on opposite sides of the aircraft who logged sighting occurrence and positions of animals using a GPS. Tape on the wing-struts of the aircraft were used to define a transect width of 400 m on the ocean surface, and animals were only counted if they were recorded within this transect (Fig. 1b). The flight plan followed a fixed line transect through a series of 17 waypoints adjacent to the coast (Fig. 2), flying at a height of 305 m (1000 ft), at a constant speed of 100 knots and at 2 nautical miles distance from the coast. The total length of the transect was approximately 610 km, while the time required for each survey varied between 4 to 6 hours, depending on the number of sightings and time spent circling animals observed from the plane. Each sighting of a large whale or of a pod of 5 or more dolphin-sized mammals was circled to obtain species identifications and photographs.

The September survey followed a different flight-path as a result of aircraft problems that greatly reduced the total flying time. These required that the plane flew west-ward first, then returned to the airport at Dili for refuelling, before continuing the survey along part of the southern coast.

Figure 1. Aircraft used for the aerial surveys (a), and tapes on wing-strut marking the transect width for the observer on the port-side of the aircraft (b).

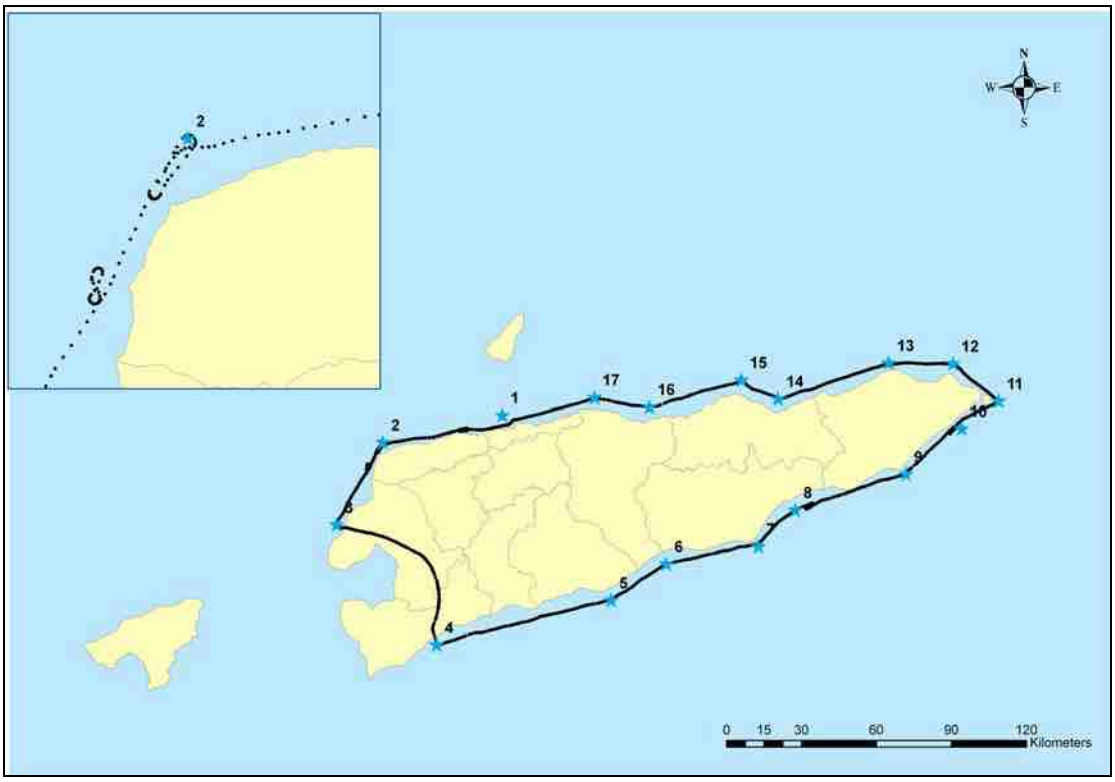

Figure 2. Flight plan of aerial surveys on map of Timor Leste with numbers indicating fixed waypoints along the coast. Large animals or large groups of animals were circled for species identification and photography (inset).

Data recording

Sightings and environmental data were entered on datasheets during the flights (see Appendix 1). Animals were pooled into taxonomic groups (e.g. dolphins, large whales, rays, turtles) however, at some times it was not possible for observers to distinguish among dolphins, small dolphin-sized whales and dugongs from the plane. In such cases, the sighting was labelled as “small marine mammal(s)”. For each sighting the identity, total number and GPS position was recorded on datasheets. A hand-held GPS was used to track the flight path and to mark the waypoints of the beginning and end of each survey and of each sighting. Environmental data were recorded throughout the flight at waypoints and included cloud cover, Beaufort sea-state, turbidity and glare. Categories of environmental variables are shown in Appendix 2.

During the July, August and September surveys, data were recorded on a digital voice recorder that was time-coded to enable matching of sighting data with the GPS waypoints. This technique reduces the chance of ‘missing’ a sighting while writing on the datasheet and thus can increase accuracy and reduce time spend on analysis of sightings. As this type of data recording is still under development for the marine megafauna surveys in Timor Leste, these results have not been analysed and reported here.

Boat survey

Surveys were conducted using the motor vessel the K.M Mitra Abadi from the 25th – 28th November 2008 with the primary objective of obtaining species identifications of marine megafauna. The survey focused on the north coast of Timor Leste (Fig. 3) close to Dili Harbour due to the range and speed of the vessel. Four observers, two on the cabin-top and two at the bow of the vessel, scanned the ocean surface using binoculars for megafauna (Fig. 4a-c). Once a sighting was made, the vessel approached until species identification was possible. Photographs were taken during sightings to confirm identifications whenever possible.

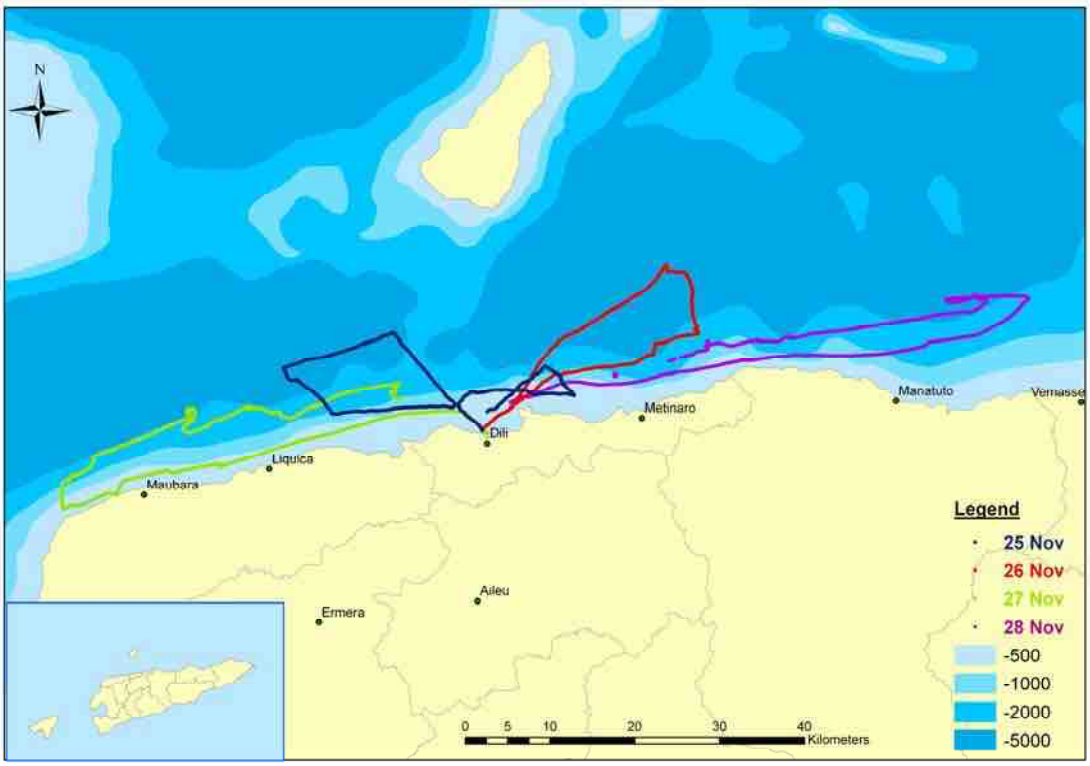

Figure 3. Research vessel survey tracks from November 25 – 28, 2008

Figure 4. Research vessel K.M Mitra Abadi (Timor Tiger (a)), and observers on the bow (b) and roof (c) of the vessel.

Data analysis

Data were transcribed to computer spreadsheets for storage and basic statistical analyses. GPS way-points and tracks were downloaded to spreadsheets with Mapsource (Garmin Mapsource®, version 6.12.4). Sightings and tracks were mapped using ArcGIS (ESRI® ArcMap™ 9.2).

Capacity building

Training was provided on aerial survey techniques and species identification, through discussions and the preparation of an aerial survey manual. This manual contains information on methodologies and materials necessary to conduct the aerial surveys, similar as described in this report. On board the ship, training was provided through participation in spotting and identification of the observed animals. Species identification training was done using a comprehensive identification guide (Jefferson *et al.* 2008).

Results

A high diversity of marine megafauna was sighted during the aerial surveys and included small marine mammals (such as dolphins, dugongs, and small whales), large whales, whale sharks, sharks, rays and turtles (Table 1). Most of the dolphins and smaller whales were identified to species during the boat survey and the combined surveys revealed a total of thirteen different species of cetaceans (Table 2 and Appendix 3).

Fish/cephalopod feeders

Sightings of dolphins and small marine mammals during aerial surveys were broadly distributed along the entire coastal region of Timor Leste, with most recorded in the northwest and northeast (Fig. 5). These small cetaceans were sighted throughout most of the year, but largest numbers were recorded in November (Table 1). During this month, very large pods of several hundreds of animals were sighted moving eastwards and they appeared to be foraging. The boat surveys revealed that these large pods were mixed species groups of dolphins (e.g. spinner and Fraser dolphins) and small whales (e.g. false killer and pilot whales). There were only six sightings of sharks during the aerial surveys, four of which occurred during the June flight (Table 1).

Large whales and whale sharks

Most of large whale and whale sharks were sighted in the north-western coastal waters offshore from the Dili and Liquisa districts (Fig. 6). The majority of whales were blue whales (*Balaenoptera musculus*), with two adults sighted in September and a group of two adults with a calf sighted in November. One sighting was made of what was either a Bryde's (*Balaenoptera borealis)* or a sei whale (*Balaenoptera borealis*) in the northeast during the November survey and involved a mother with a calf. The single sperm whale (*Physeter macrocephalus*) sighted during the June survey was identified based on its blow, which was angled to the side and on the row of crenulations (bumps) on the dorsal ridge of the tail stock observed as the animal dived. There were three sightings (in May, July and November respectively) of large whales whose identities could not be confirmed.

Only three sightings were made of whale sharks (*Rhincodon typus*); in May, June and November. All encounters were brief and animals could not be photographed to confirm identification, although their square head and spotted pattern of the skin are very distinct, even from 1000 feet height. All individuals appeared to be relatively small (3-6 m), immature animals.

Other marine species

Turtles were sighted in all surveys and numbers peaked in November, with the greatest abundances occurring around the far north-eastern tip of Timor Leste, off-shore from the Lautem district and southeast of Jaco Island. Here, large numbers of turtles were observed to be foraging in the shallow coastal waters. Rays of unidentified species were sighted from July to November throughout most of the coastal area, with peak abundances occurring in November (Table 1). Several groups of five or more manta rays (*Manta birostris)* were photographed during this month. Dugongs (*Dugong dugong*) sightings were relatively rare, with individuals recorded in June (n = 1) and in November (n = 5).

Spatial and temporal trends of sightings

Sightings of marine megafauna along the coast of Timor Leste ranged from single individuals to large pods of up to several hundred animals (Table 1 and Fig. 7). While sightings were well distributed along both the north and south coasts (Fig. 7), the majority of the large whale and whale shark sightings were made in the north-west, near Dili (Fig. 6). Similarly, the most of the large pods of dolphins and small marine mammals were observed along the north coast (Fig. 7).

The cumulative sightings across all months suggest that the highest diversity of marine megafauna occurs in north-western coastal waters, west of Baucau (Fig. 7). However, the reported data have not been corrected for the environmental conditions during the separate surveys, which is likely to have influenced precision of observations and identification.

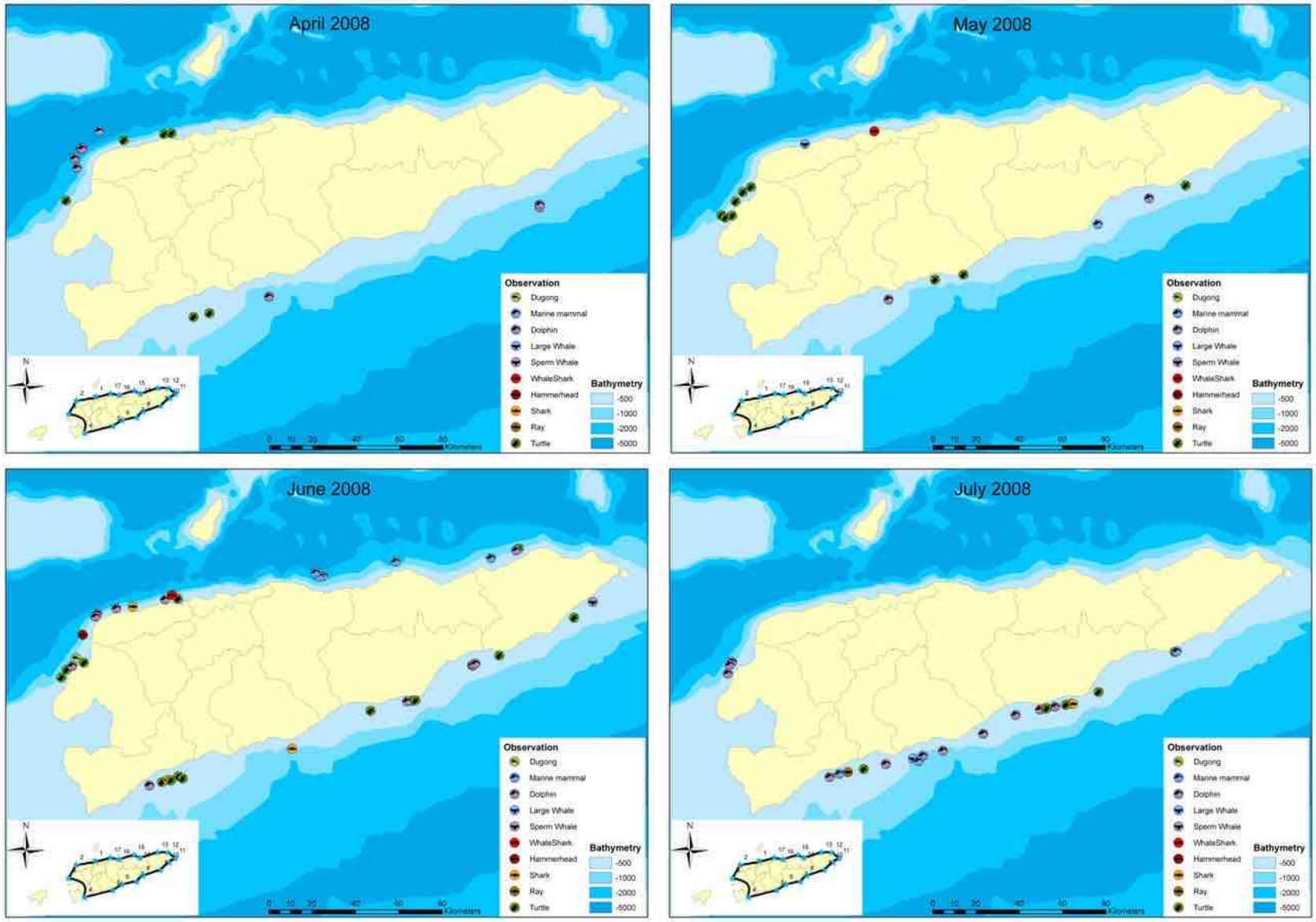

Figure 5. Sightings per month, clustered into broad taxonomic groups. Inset shows flight-paths and fixed waypoints.

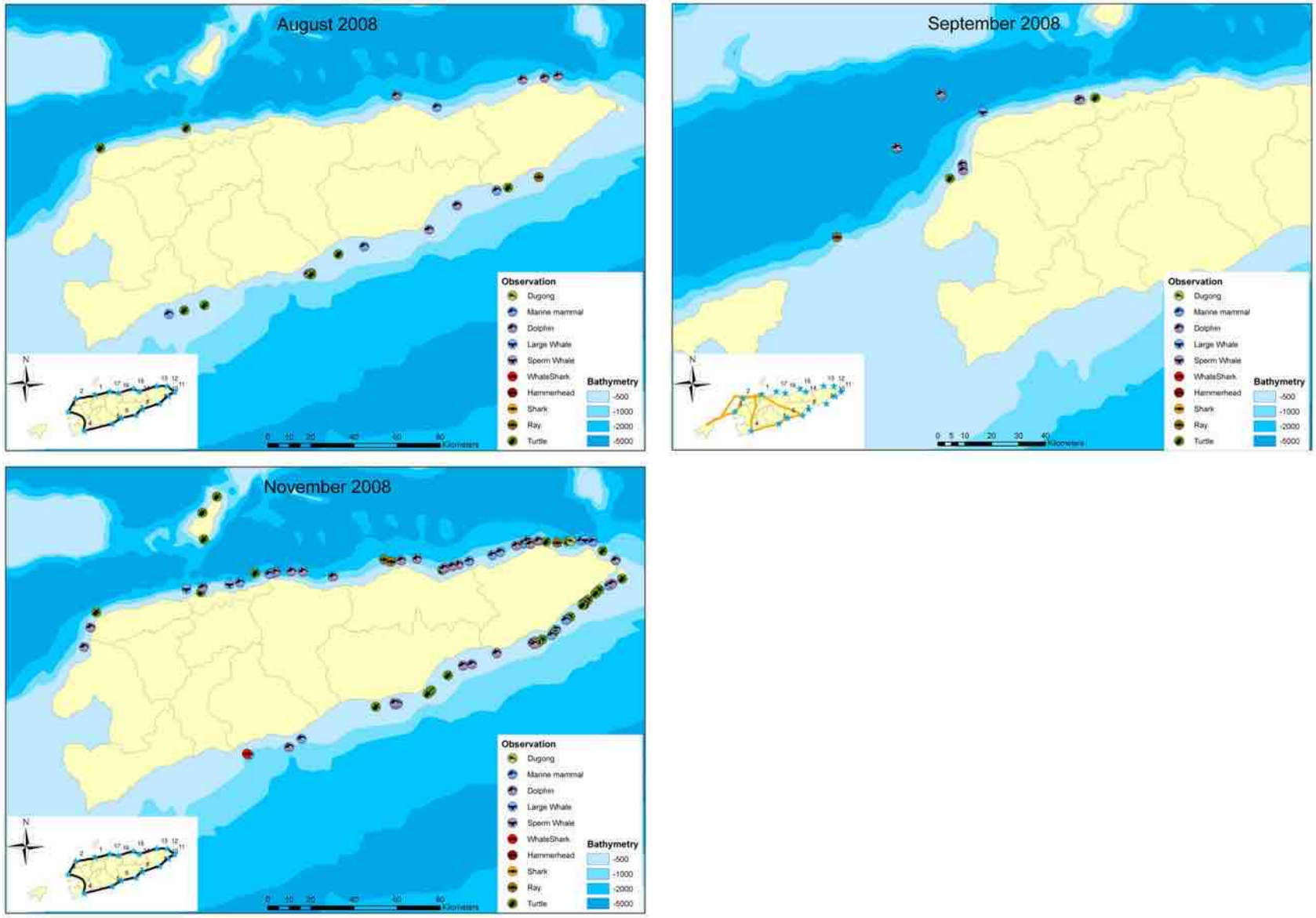

Figure 5. (continued) Sightings per month, clustered into broad taxonomic groups. Inset shows flight-paths and fixed waypoints. Note that the September flight-path was shorter than other months (see text for explanation).

Table 1. Broad taxonomic groups and total abundance of marine megafauna as observed during seven aerial surveys conducted in 2008, two nautical miles offshore along the coast of Timor Leste.

Date	**April 21**	**May 27**	**June 17**	**July 16**	**August 13**	**September 24**	**November 5**
Dolphin	200	5	120	165	230	350	1300
Small marine mammal	1	20	35	25	20	3	190
Dugong			1				5
Manta ray *(Manta birostris)*							5
Ray				1	1	1	9
Shark			3	1			
Hammerhead shark (*Sphyrna spp.*)			1				1
Whale shark (*Rhincodon typus*)		1	1				1
Sperm whale (*Physeter macrocephalus*)			1				
Blue whale (*Balaenoptera musculus)*						2	3
Sei whale (*Balaenoptera borealis*)							2
Large whale		1		1			1
Turtle	7	9	22	7	9	2	44

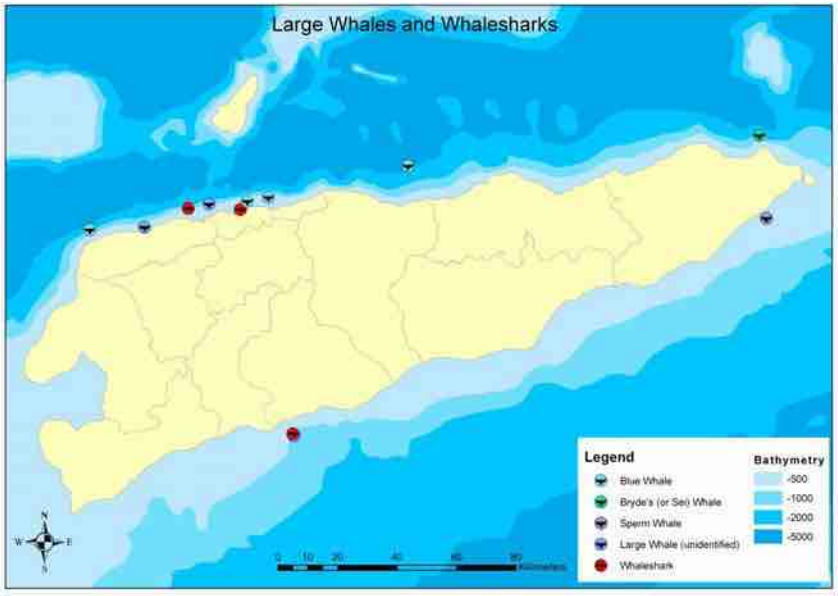

Figure 6. Sightings of large whales and whalesharks during aerial and boat surveys

Table 2. Cetacean species sighted during the boat survey and their IUCN status (EN = Endangered, VU = Vulnerable, DD = Data deficient, LC = Least Concern)

Common name	**Scientific name**	**Indonesian name**	**IUCN status**
blue whale	*Balaenoptera musculus*	Paus biru	EN
sperm whale	*Physeter macrocephalus*	Paus sperma	VU
sei whale	*Balaenoptera borealis*	Paus sei	EN
or Bryde's whale	*Balaenoptera brydei*	Paus Bryde	DD
short-finned pilot whale	*Globicephala macrorhynchus*	Paus sirip pendek	DD
false killer whale	*Pseudorca crassidens*	Paus pembunuh palsu	DD
pygmy killer whale	*Feresa attenuate*	Paus pembunuh kerdil	DD
melon-headed whale	*Peponocephala electra*	Paus kepala semangka	LC
Cuvier's beaked whale	*Ziphius cavirostris*	Paus paruh Cuvier	LC
rough-toothed dolphin	*Steno bredanensis*	Lumba-lumba gigi kasar	LC
Rissos's dolphin	*Grampus griseus*	Lumba-lumba abu-abu	LC
Spotted dolphin	*Stenella attenuate*	Lumba-lumba totol	LC
spinner dolphin	*Stenella longirostris*	Lumba-lumba paruh panjang	DD
Fraser's dolphin	*Lagenodelphis hosei*	Lumba-lumba Fraser	LC

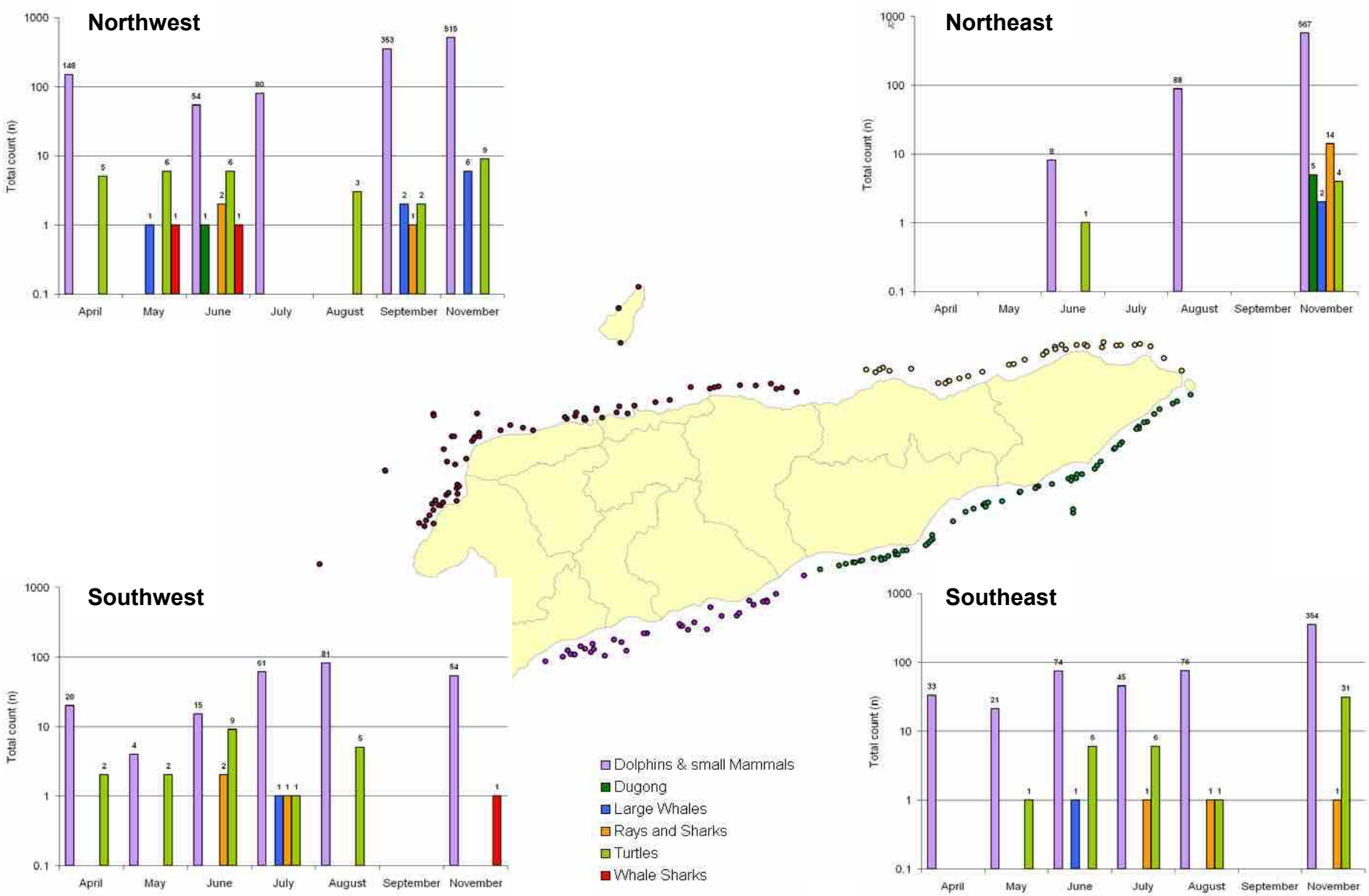

Figure 7 Monthly abundance of marine megafauna from April – November 2008. (note the log-scale of the y-axis)

Discussion

The primary aim of this study was to determine if cetaceans and other megafauna aggregated in the nearshore waters of Timor Leste, and if so, to assess opportunities for regional ecotourism industries. Worldwide, successful ecotourism industries based on megafauna interactions generally have some combination of three important attributes: firstly, the industry offers a unique opportunity to interact with megafauna, either due to their rarity (i.e. one of the few places in the world where animals can be seen/accessed), quality of the experience (tourists are able to closely approach or directly interact with the fauna) and/or abundance and diversity of the animals. Secondly, the animals are accessible using logistics and infrastructure in place in the country. Thirdly, the animals occur in a predictable manner so that investments can be made in the future of the industry. Here, we discuss the results of our study within this context.

Species diversity

This survey provided the first description of the marine megafauna inhabiting the Timor Leste's off-shore waters and shows that these waters contain an exceptional diversity of species. A total of 13 cetacean species were recorded as well as individuals from an additional seven other taxonomic groups. The diversity of cetaceans recorded for Timor Leste is similar to that found in the nearby Solor-Alor Strait region, where Kahn (2005) recorded a total of 15 species, 12 of which were sighted during dedicated boat-surveys and an additional three species recorded from interviews with fishermen from Lamalera. In comparison, ten species (including two sub-species) were recorded in the tropical waters of East Kalimantan, Indonesia, and only four of these were sighted in off-shore waters (> 50 m depth, Kreb and Budiono, 2005). Ten species were also recorded in La Re´union (Dulau-Drouot *et al.* 2008) in the western Indian Ocean, which has a very narrow continental shelf and depths rapidly increasing near the shore, similar to the off-shore geography in Timor Leste. In the western Atlantic, nine species were recorded in waters around the Bahamas (MacLeod *et al.* 2004), and the cetacean diversity in the Canary Islands in the eastern Atlantic matches that of Timor

Leste, with 13 species recorded in nearshore waters (Perez-Vallazza *et al.* 2008). Given this context, our results and those of Khan (2005) suggest that the ocean surrounding Timor Leste are part of a regional system with a diversity of cetaceans that is globally unique.

Conservation

At least seven of the species recorded by our study, including three of the whales (Table 2), the dugong, hammerhead shark, whale shark and turtles are listed in the IUCN Red List of Threatened Species™ (2007) as facing a higher risk of global extinction (Endangered or Vulnerable status). Five of the cetacean species are not evaluated because of insufficient information (Data Deficient), and six cetaceans have been evaluated to have a low risk of extinction and are classified as Least Concern (IUCN 2007).

Distribution and abundance

Marine megafauna were sighted in nearshore waters along the entire length of the Timor Leste coastline surveyed by our study. However, the greatest abundances of animals were sighted along the northern shoreline and numbers peaked during the month of November, when very large pods of several hundreds of dolphins (spinner and Fraser dolphins) and small whales (false killer and pilot whales) were sighted.

Since these large abundances of animals were not present throughout the remainder of the surveys, it is likely that we observed a migration event during November. The deep water channels between Timor Leste and the Indonesian Archipelago are known to be a migratory route for cetaceans (Kahn 2003, 2005), although the drivers of the pathway and timing of the event are unknown. For many other cetaceans, migrations take place for reproduction and/or feeding events (Boyd 2004, Stevick 2002) and follow a variety of cues such as the spatial and temporal distribution of resources and habitat, seasonal variation in sea surface temperature (SST) and currents (e.g Perez-Vallazza *et al.* 2008, Rasmussen *et al.* 2007). The geographic extent and direction of oceanic migration of a species can also vary among populations and among individuals within a population (Alerstam *et al.* 2003).

The increase in numbers of cetaceans in Timor Leste waters coincided with an increase in SST. SST was coolest in August and then rapidly increased by approximately 3^{o}C until November/December (Fig. 8). Similar patterns in distributions of predatory fishes such as tuna have been observed with increasing SST or higher SST ranges (Myers and Hick 1990; Schick *et al.* 2004) and in the Ningaloo region of Western Australia, the patterns in relative biomass of fish/cephalopod feeders were explained to some extent by SST (Sleeman *et al.* 2007). In these studies it was suggested that warmer waters might increase primary productivity and provide better food availability for cetaceans and other marine megafauna, but it is not known if this was the case in our study.

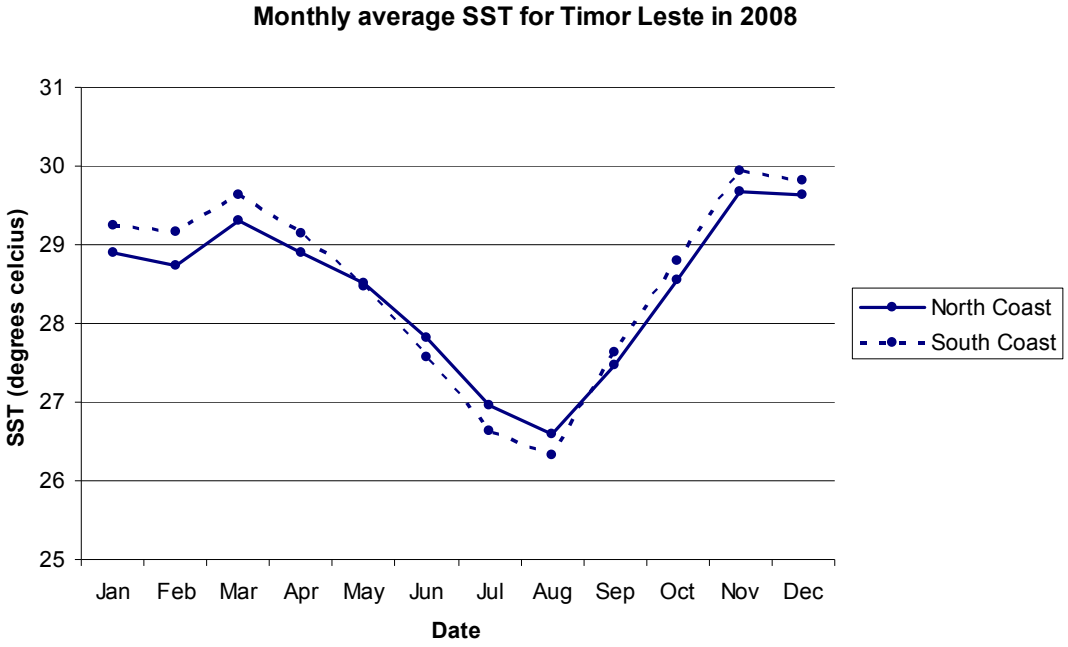

Figure 8. Monthly average SSTs for the northern (at -8.5° latitude) and southern (at -10.5° latitude) coastal waters of Timor Leste in 2008. (source: NOAA NCEP EMC CMB GLOBAL Reyn_SmithOIv2 monthly dataset).

The timing of the migration also coincides with a flow reversal and associated reduction in the surface currents of the Indonesian Through-Flow (ITF), which forms the main passage from the western Pacific Ocean to the eastern Indian

Ocean (Molcard *et al.* 2001, Wyrtki 1987). The Ombai Strait and the Timor Passage, north and south of Timor respectively, are part of the primary inflow and outflow portals of the ITF (Gordon 2005). Here, cool, low-salinity, well ventilated water from the north Pacific inflows through the upper thermocline of the Makassar Strait, and more saline South Pacific water through the lower thermocline of the eastern Indonesian seas (Gordon and Fine 1996). Around Timor currents (reaching up to 150cm/s in the upper 200 m) are channelled into the passage between Alor and Timor Islands and are directed in a northwest direction, towards the Savu Sea throughout most of the year (Molcard *et al.* 2001). However, there is a strong reversal in November/December, with a northeast current in the first 160 m (Molcard *et al*. 2001). While the effect of this event late in the year is unclear, it is possible that the reversed flow is associated with an increased food productivity favourable for cetaceans. Alternatively, the slackening of the flow late in the year may provide better conditions for animals to migrate through the Ombai Strait.

The abundance of cetaceans contrasts with the limited number of sightings of whale sharks and other large elasmobranchs by our study. Bajo and other fisherman from Roti and Kera Islands, off the western tip of Timor Island reported frequent sightings of whale sharks during the east monsoon period from August until the beginning of the west monsoon in November (Stacey *et al.* 2008). According to these fishermen, whale sharks occur regularly in the Timor Passage south of Roti Island and also offshore from Suai (south-western Timor Leste), as well as in the coastal waters near Kupang, West Timor and in the Savu Sea between Timor and Flores Islands. In our study only three sharks were sighted. This suggests that this species is unlikely to form the basis of an ecotourism industry in Timor Leste.

The north coast of Timor Leste provided the most accessible area to view marine megafauna. Sea conditions on the south coast were often rough and road access to the coast and port facilities are very limited. In contrast, the generally calmer waters on the north coast and proximity of megafauna to the coastline offer better opportunities for development of an ecotourism industry.

However, such an industry would require the predictable appearance of megafauna on a year-to-year basis. In order to ensure that this occurs, further work will be required to document the occurrence of megafauna around the time of November and to confirm that this is a predictable event. This work should consist of both boat-based and some limited aerial surveys to build on the current information on species diversity, abundance and distribution provided by the present study. In addition, identification of migratory pathways will require tagging studies (satellite telemetry and genetic fingerprinting) and some knowledge of the ecological drivers of this behaviour. This could be provided by oceanographic and trophic studies in the Wetar-Ombai Straits.

Ecotourism – social and biological issues

Whale and dolphin watching has proved to be one of the most successful and resilient types of marine ecotourism in the world, offering economic returns and community, educational, research, and conservation benefits (Hoyt 2007). The unique diversity, accessibility and predictability of cetaceans and other marine megafauna in Timor Leste provides good potential for development of marine ecotourism. However, the development of such an industry requires great care, because cetacean watching brings along a great risk of excessive disturbance: too many boats moving too close to the animals, possibly resulting in avoidance of the region by the animals or increased chances of boat strikes. To be genuinely sustainable as an industry, cetacean watching should be both ecologically and economically sustainable. The Nino Konis Santana National Park and other potential future marine protected areas in Timor Leste can play a strategic role in managing cetacean watching, for example, through the establishment of ‘no go zones” that might provide areas for cetaceans to be free from disturbance. Most countries and communities involved in cetacean watching have some regulations, including codes of conduct with which tourist operators are asked to comply. Ideally, the development of an industry based on marine megafauna would have two main focal points; firstly, to make a contribution to the conservation of threatened species and secondly, have direct benefits to local people, including capacity building, the transfer of industry skills, and support for community development. This study provides some baseline

information necessary to perform analyses of ecotourism potential based on marine megafauna in Timor Leste.

Recommendations

Based on this preliminary study of marine megafauna diversity and abundance in Timor Leste's coastal waters and the potential for ecotourism, we recommend the following actions;

- Aerial and boat-based surveys and acoustic studies are required to build on the current information on species diversity, abundance and distribution and to identify behavioural activities and patterns, particularly around the time of November.
- Tagging studies using satellite telemetry and/or genetic fingerprinting are required to define migratory pathways, identify populations and connectivity.
- Oceanographic and trophic studies in the Wetar – Ombai Strait to identify key seasonal and localized upwellings, primary and secondary productivity, and potential key prey species of cetaceans.
- Surveys of traditional ecological knowledge are required to complement aerial and boat survey data.
- Training and capacity building on survey techniques, species identification, marine megafauna biology and conservation.
- Capacity building for community-based whale- and dolphin watching ventures
- Development of cetacean watching policies, guidelines, regulations and compliance
- Identification of threats to megafauna in Timor Leste waters
- Government policies for deep-sea and shallow-water cetacean habitat protection and threatened species management.

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Appendix 1 Sample data sheet

Aerial Surveys of Large Vertebrates

Date and Flight:

WS	Whaleshark
LW	Unidentified Large Whale
HW	Humpback Whale
SW	Sperm Whale
Hh	Hammerhead shark
Sh	Unidentified shark
Do	Unidentified dolphin or small toothed whale
M	Unidentified mammal of dolphin or small toothed whale size
Du	Dugong
T	Turtle
R	Ray
Ss	Seasnake

Observer:
co-observer 1:
co-observer 2:
Position in plane:
Start time:
Start Location:
End Location:

Glare	0-3
Cloud	0-9
Turbidity	1-4
Beaufort	0-6

Time	Animal	# Total	# Adults	# Calves	Outside transect	Close up	Comments	*Longitude*	*Latitude*
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	
	Glare:				*Cloud:*		*Turbidity:*	*Beaufort:*	

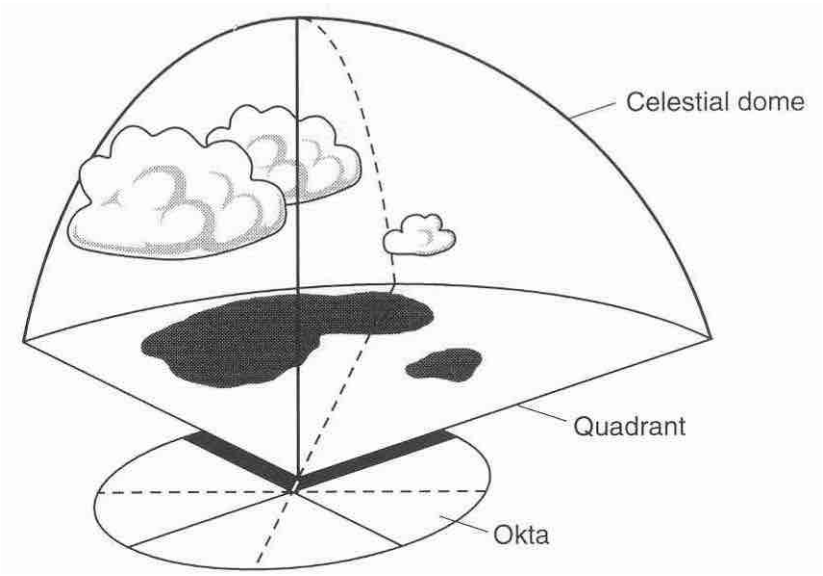
Appendix 2 Environmental data

(adapted from Hodgson and Marsh 2006)

1. Cloud Cover

Cloud cover is estimated according to the number of eighths (octas) of the sky (celestial dome) that are covered in cloud. It is easiest to divide the sky into quadrants, estimate the percentage cover in each quadrant, and add these to provide a total percentage cover (figure from English *et al.*, 1997)

Octa	Percentage Cloud Cover
0	0%
1	12.5%
2	25%
3	37.5%
4	50%
5	62.5%
6	75%
7	87.5%
8	100%



2. Beaufort Scale for Sea State

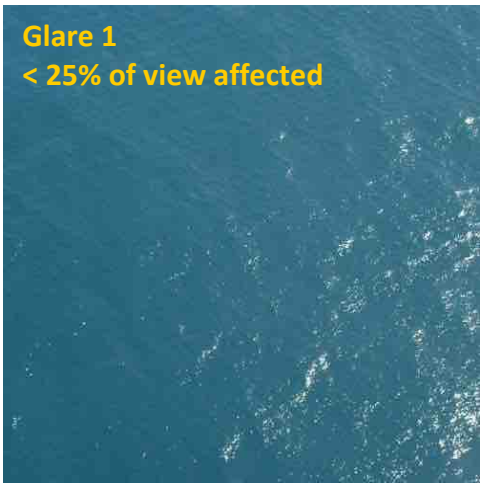
FORCE	DESCRIPTION	SEA STATE		SPEED	
				knots	m/s
0	calm	like a mirror		<1	0.0-0.2
1	light air	ripples, no foam		1-3	0.3-1.5
2	light breeze	small wavelets, smooth crests with glassy appearance		4-6	1.6-3.3
3	gentle breeze	large wavelets, some crests break, some white caps		7-10	3.4-5.4
4	moderate breeze	small waves, frequent white caps		11-16	5.5-7.9
5	fresh breeze	moderate rather long waves, many caps, some spray		17-21	8.0-10.7
6	strong breeze	some large waves, extensive white foam crests, some spray		22-27	10.8-13.8

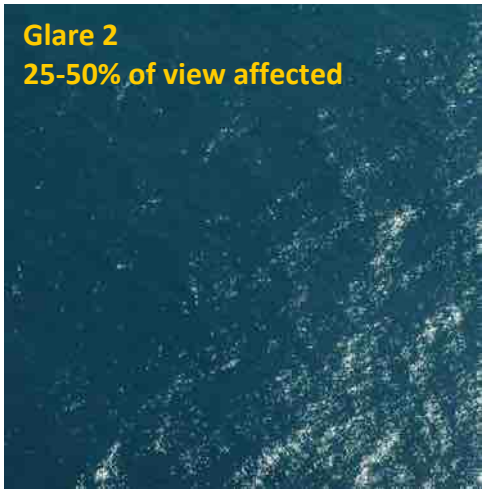
3. Turbidity

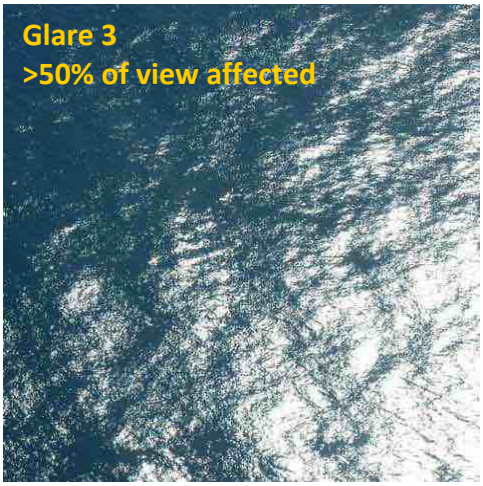
Water Quality	Depth Range	Visibility of Sea Floor	Turbidity
Clear	Shallow	Clearly visible	1
Variable	Variable	Visible but unclear	2
Clear	>5m	Not visible	3
Turbid	Variable	Not visible	4

4. Glare Intensity

Four categories for glare intensity determined according to what percentage of the observers view is interrupted by glare.







Appendix 3 Photo identification of marine megafauna species observed in this survey

Spotted dolphins (*Stenella attennata)*

Spinner dolphins (*Stenella longirostris)*

Fraser dolphins (*Lagenodelphis hosei)*

Rough-toothed dolphins (*Steno bredanensis)*

Short-finned pilot whale (*Globicephala macrorhynchus)*

Short-finned pilot whales (*Globicephala macrorhynchus)*

Melonheaded whales (*Peponocephala electra)*

Manta rays (*Manta birostris)*

Blue whale (*Balaenoptera musculus)*

Sei whale (*Balaenoptera borealis)*

Spermwhale (*Physeter macrocephalus)* stranded near Mauburo, Liquisa district