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Diversity and distribution of cetaceans in the Republic of Palau

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ABSTRACT

Context. Until recently, very little was known about the species diversity and occurrence of cetaceans in the Republic of Palau. A dedicated scientific investigation into the occurrence and distribution of island associated cetaceans in Palau was conducted in 2012 and 2013. **Aims.** The aim of this project was to investigate the diversity and distribution of cetaceans in Palau to inform management and build local capacity in cetacean science. **Methods.** Following a feasibility study in 2010, a vessel-based visual and acoustic line transect survey was conducted in 2012, covering a survey area of 4319 km^2. The survey was repeated and expanded in 2013 using aerial methods. Additionally, small boat work was conducted in areas with high cetacean density to obtain genetic, acoustic, and photographic samples. In 2019, a vessel-based visual and acoustic survey of the Southwest Islands was conducted. **Key results.** By combining the survey results with anecdotal sightings, a cetacean species inventory for Palau was established. The presence of 15 species was confirmed, while four species were identified as probably present and three as likely. **Conclusions.** Survey results contributed to the management of cetaceans in the Palau Marine Mammal Sanctuary. The surveys raised local interest in cetaceans and, through public outreach and training, precipitated advancements in capacity building for cetacean management, along with a baseline for ongoing monitoring. **Implications.** This study provided the first systematic, scientific investigation using multiple survey methods into the occurrence and distribution of cetaceans in Palau, highlighting the importance of conserving cetacean populations in this region.

Keywords: cetaceans, conservation, distribution, diversity, inventory, management, Palau, species.

Introduction

Over half of the world's known species of cetaceans occur in the Micronesia region (Reeves *et al.* 1999); however, there is a lack of knowledge about the occurrence of marine mammal populations and the impacts of natural and anthropogenic threats, such as unregulated tourism, to them in this region (Miller 2007). Species diversity, abundance and distribution information is an important basis for the management of cetaceans within national jurisdictions but resource, capacity and logistical constraints hinder Pacific Island countries and territories from being able to obtain this information through systematic vessel or aerial-based scientific surveys (Hammond *et al.* 2021).

Located at 7.5150°N, 134.5825°E in the west of the Pacific Islands sub-region of Micronesia, the Republic of Palau (referred to hereafter as Palau) is made up of 586 discrete islands within an Exclusive Economic Zone (EEZ) covering 629 000 km^2. Palau shares maritime boundaries with the Federated States of Micronesia to the east, the Philippines to the west and Indonesia to the south. The country's geographic proximity to the epicentre of global marine diversity, the Coral Triangle (Veron *et al.* 2011), combined with its relative isolation and geological diversity, contribute to Palau's high rates of marine biodiversity (Palau Conservation Society 2016). Palau is best known for its pristine, diverse, and abundant marine resources that have anchored productive tourism and fisheries industries (Colin 2009). With more than 30% of its near-shore areas under protection, and one of the region's first, national protected area financing mechanisms established to support protected area management (Friedlander *et al.* 2017), the national

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government has protected species of conservation concern within its entire EEZ since 1994 under the national Marine Protection Act. Correspondingly, in 2009 Palau established the Palau National Shark Sanctuary (Hari *et al.* 2022), in 2010 there was a ministerial declaration of the Palau Marine Mammal Sanctuary (NEPC 2019) and in 2015, Palau extended protection to 80% of its EEZ with the establishment of the Palau National Marine Sanctuary (Mulalap 2016).

Historically, scientific research and management of marine mammals in Palau has been targeted primarily at Palau's critically endangered population of dugongs (*Dugong dugon*), one of the world's most isolated, estimated at 50–200 individuals (Davis 2004; Marsh 2011). Dugongs are highly valued by Palau's communities as a traditional icon, and historically as a delicacy reserved for special ceremonial occasions. National legislation bans all poaching, harassment, and capture of dugongs (Kitalong 2008).

However, scientific research targeting cetaceans in Palau has been limited. Recorded sightings have been mainly anecdotal or limited to incidental sightings, stranding events, and rapid ecological assessments (Miller 2007), with no targeted research on cetaceans conducted before 2012. Anecdotal evidence prior to 2010 suggested 13 cetacean species were present, but this number is likely an underestimate of species diversity (Andrews 2010).

Palauan people place high cultural value on the conservation of natural resources through a system of customary area and species protection called 'Bul'. Cetaceans have never been consumed as a Palauan cultural practice, have high cultural conservation value, and are in cultural records through anecdotal stories of human–cetacean interactions and observations of events such as stranded animals (B. A. Salii, pers. comm.; Chief N. A. Kumangai, pers. comm.). Traditionally, most Palauan people interact with marine species within the large lagoonal and shallow coastal water habitat, thus reducing the potential for sightings and interactions with cetacean species that occur in deep water beyond the barrier reef. Except for the Southwest Island community, who are surrounded by pelagic habitat and species, most community members indicate that large whales do not regularly occur in Palau, and that spinner dolphins (*Stenella longirostris*) and short-finned pilot whales (*Globicephala macrorhynchus*) are seen along the reef edge where traditional canoe fishing and tourism activity occurs, thus biasing sightings effort. These anecdotal sightings data are obtained from a previously unpublished report by Andrews (2010) titled 'Feasibility of Whale and Dolphin Watching Tourism in Palau' (commissioned by the South Pacific Whale Research Consortium), which we present herein. Anecdotal cetacean sighting maps generated from this work, which represent community knowledge of cetacean distribution, were used to identify hotspot areas for further investigation and to direct small boat work for biopsy sampling in 2013.

Here, we report results and synthesise information regarding cetacean diversity and distribution in Palau's waters, based on anecdotal sightings assessments compiled until 2010 and the first dedicated cetacean surveys undertaken in 2012, 2013 and 2019 (under permits; Southern Cross University Animal Research Authority 11/40; Southern Cross University EPBC permit # 2007-0005; CITES PW13-074; MNRET Marine Research Permit # RE-12-20). This work was conducted in order to fill gaps in knowledge and thereby assist in effective management and conservation. The primary purpose of the surveys was to identify species present in Palau waters, characterise the commonness or rareness of those species, and define areas of important habitat.

Materials and methods

Cetacean watching feasibility study 2010

In 2010, two of the authors (O. Andrews and T. Holm) conducted a whale and dolphin watching feasibility assessment focused on two methods of information gathering. A series of organised interviews were conducted with 30 community stakeholders; these represented six of the main marine tourism operations, charter and sports fishers, pilots, government officials, parliamentarians and non-government organisations (NGOs) who were deemed by local authorities to have a high level of marine experience and expertise. Each participant was presented a map of the area and a cetacean identification chart (IFAW and SPREP 2005) to review and discuss. Participants were asked to identify on the map where small and large cetacean species occur in the lagoon, in nearshore and offshore areas, which species, how frequently they are sighted, and what time/s of year they are present. Opportunistic sightings surveys were also conducted over a 7-day period, 6 days on board local dive tourism boats and one day on a helicopter flight. The area surveyed included the south-western coast to seaward of the lagoon between Peleliu Island and Ulong Bay.

Line transect surveys 2012

Line transect surveys are a form of 'distance sampling' widely used to estimate the density and abundance of wild animal populations, including multiple cetacean species across large areas (Buckland *et al.* 2001; Thomas *et al.* 2007; Hammond *et al.* 2021). In recent years, flexible survey methods have been developed in response to a need for cost-effective abundance estimation methods for coastal (e.g. Dawson *et al.* 2004) and freshwater (e.g. Williams *et al.* 2016) cetaceans. The 2012 Palau cetacean surveys used an approach called the 'Animal Counting Toolkit,' which follows the fundamental principles of distance sampling in terms of survey design and field protocols for data collection and analysis but embeds a 'training while doing' philosophy throughout, in order to build local scientific capacity while collecting reliable data from cost-effective, platforms (Williams *et al.* 2017). This approach has been employed in neighbouring Indonesia (Mustika *et al.* 2021) to conduct species inventories in data-deficient regions, to estimate average spatial distribution of animals to guide marine spatial planning, and to generate illustrative indices of density and abundance.

A stratified survey design (Fig. 1) was used where transects were split into two strata (north and south), within which equal-spaced zigzag or parallel transect lines were placed

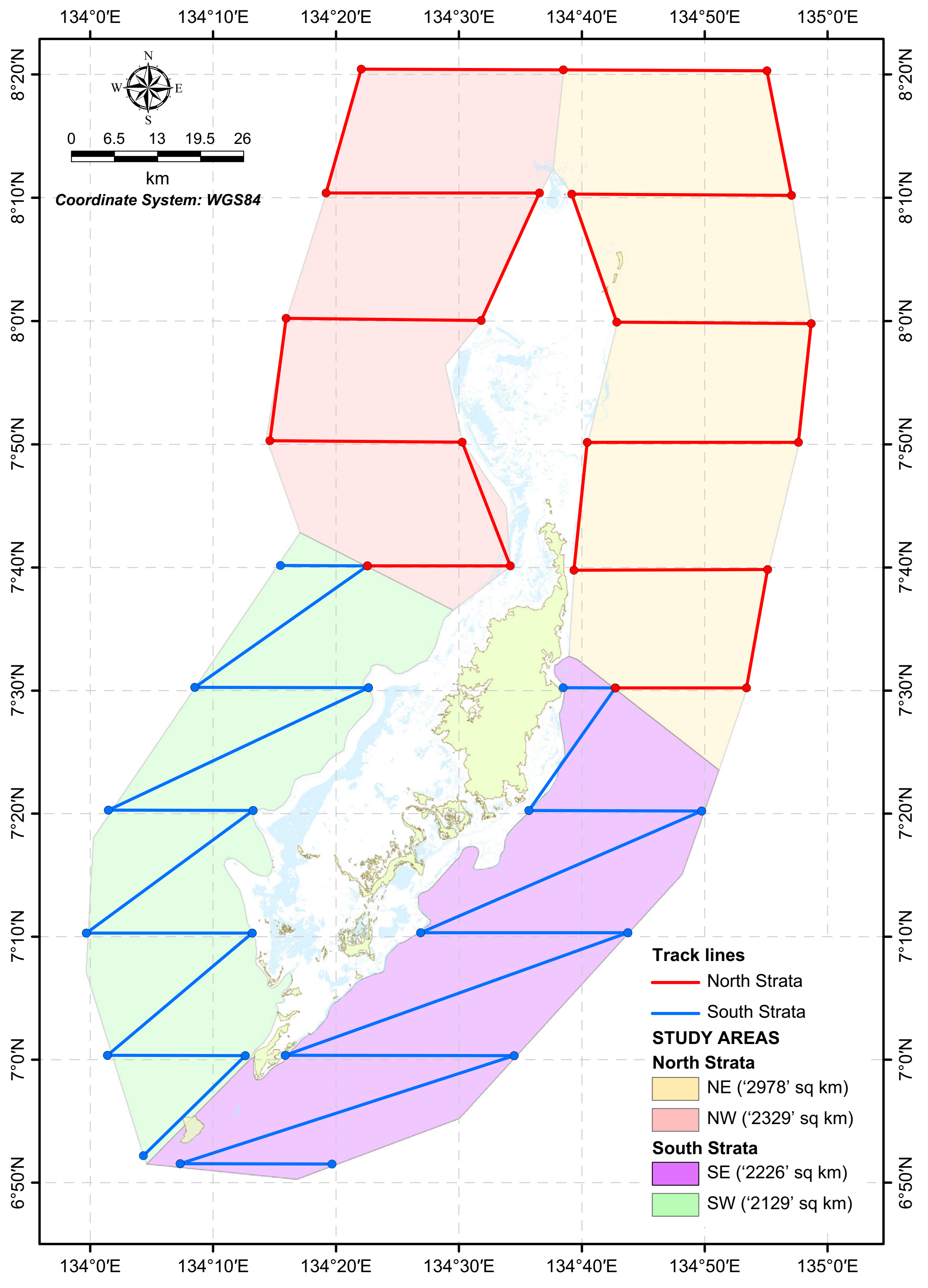

Fig. 1. Survey design for the 2012 vessel-based line transect survey (South Strata) and 2013 aerial survey (North and South Strata).

using a random start point to ensure equal coverage probability within strata (Thomas *et al*. 2007; Williams and Thomas 2007). The survey area covered for the 2012 surveys was the south strata, from the barrier reef edge to 10 nautical miles offshore, seaward of the coastline of Babeldaob, Peleliu and Angaur Islands. The area corresponds to the coastal fisheries zone of Palau's Territorial Sea and overlaps with the majority of the tourism effort.

A vessel-based line transect survey was conducted from a 45 ft catamaran, SV Endless Summer, travelling at approximately 7 knots between 19 January and 1 February 2012. As the vessel travelled along the predetermined transect lines, observations were made by two observers, each scanning 90 degrees from the midline to the port or starboard side using naked eye and binoculars, and a data recorder placed in front of the mast of the ship at an average observer eye height of 3.7 m above water. This procedure was defined as being 'on effort' (i.e. searching for animals while on transect). When marine mammals were sighted, observers determined distance and angle from the track line using reticle poles correlated to individual observer height and an angle board mounted to the mast (Williams and Thomas 2007). The data recorder concurrently recorded the date, time, location, survey effort, and sighting conditions such as Beaufort sea state, cloud cover and glare. The vessel then left the track line to go 'off effort' (also called 'closing mode' in other surveys) to approach the animal(s) and determine their species, group size, pod composition and behaviour. Photo ID data were also collected using a Canon 70D digital camera and 400 mm telephoto lens to identify individuals and aid in species identification. The visual team also included one data recorder who monitored a computer and GPS tracking program called *Logger 2000*, developed by the International Fund for Animal Welfare (IFAW), from inside the vessel and communicated to the outside observers via UHF radio to enter sightings, changes in conditions and observer rotation that was every hour, giving each observer 4-h on and 1-hour off in every 5-h block to mitigate observer fatigue. Survey effort was only conducted when the Beaufort sea state was five or less, during daylight hours, between approximately 0730 hours and 1730 hours. Linear Encounter Rates (LERs) were calculated by dividing the total number of animals of each species sighted on effort by the total kilometres travelled on effort.

Passive acoustic monitoring 2012

Passive acoustic monitoring for the 2012 survey was conducted using a two-element, towed hydrophone array. An acoustician monitored the array to listen for and record cetacean vocalisations. The array consisted of two Reson TC-4013 hydrophones that were spaced 3 m apart. The array was towed 70 m behind the vessel to reduce vessel noise. The use of a longer cable was limited by what could fit into a checked bag on a commercial airline.

Both channels from the array were fed through a high-pass filter (Magrec HP/27ST Stereo Monitor Box). Corner frequencies of the filter were set between 500 hertz (Hz) and 1 kilohertz (kHz) depending on vessel noise, and the gain set between 10 dB and 20 dB. The signals were split from the high-pass filter and fed into a PC digital interface (MOTU traveller model) and a dedicated multi-track digital recorder (Tascam DR-680). The signals from the MOTU were passed to a laptop running PAMGuard software (Gillespie *et al.* 2008). PAMGuard was used to record and monitor for marine mammals (both visually and aurally). Recordings were sampled at 192 kHz. Acoustic events and metadata, such as the GPS track and acoustic recording setup, were recorded in PAMGuard's database. The Tascam DR-680 was used as a dedicated recorder in case there was an issue with the laptop running PAMGuard. The Tascam recorded the 2-channel signal at 192 kHz and 24 bits. All recordings were reviewed at sea for marine mammal calls and noted in the database.

Triton 1.80 (Wiggins and Hildebrand 2007) software was used to decimate the recordings to 96 kHz and 2 kHz. Long term spectral averages (LTSAs) were then created from both decimated datasets to be reviewed by an experienced analyst. Acoustic events were then manually annotated. Each .wav file was analysed visually and aurally for marine mammal vocalisations. If a vocalisation was detected, an acoustic event was created and logged. The type of vocalisation, along with the start and end time of the encounter were recorded. Unique acoustic events were defined as periods of vocalisations separated by at least 10 min of silence.

Aerial surveys 2013

The 2013 aerial surveys used the same transects that were covered during 2012 (south strata in Fig. 1), but also covered the northern strata that had not previously been surveyed, thus surveying the complete survey area 10 nautical miles to seaward around Palau's main island group. Aerial surveys covering the south strata were conducted on the 20 and 21 April 2013 at an altitude of 183 m (600 ft) at a speed of 80 knots from a helicopter with the doors removed, taking off from Malakal Island, Koror. One observer was positioned in the back left seat of the helicopter and a second observer sat in the back right seat. A data recorder sat in the front left seat of the helicopter and ran the *Logger 2000* program, which was used to enter all survey data and to store the helicopter's GPS position every second. Information on Beaufort sea state, sightability score (1, Very poor – 5, Excellent), swell height, percent cloud cover, weather conditions such as rain, overcast and glare, was recorded, as well as cetacean sighting information: location, species, group size, group composition, behaviour and corresponding photographic frame numbers for identification. Photographs were taken with a Canon 70D digital camera and 400 mm telephoto lens. Inclinometers were used to measure the angle of declination from the observer to the cetacean. For some sightings, observer effort was halted while the helicopter conducted a racetrack manoeuvre to go back over a cetacean sighting to confirm species and group size. An eight seat, Britten Norman Islander, twin-engine, fixed wing aircraft (BN2A) taking off from Roman Tmetuchl International Airport, flying at a speed of 90 knots at an altitude of 183 m (600 ft), was used to survey the northern strata on 24 April 2013, applying the same protocols.

Small boat surveys 2013

In addition to the aerial survey, non-systematic small boat work was conducted from a Bureau of Marine Resources patrol boat (7-m open fibreglass skiff with two × 150 hp outboard engines). Survey effort targeted areas of high cetacean density over an eight-day period 12–25 April, 2013 to collect acoustic, genetic and photo ID data. The vessel followed a random track. Two observers and a data recorder scanned 360 degrees around the vessel. When cetaceans were encountered, observations were recorded including sighting date, location, species, pod size, and behaviours observed as well as effort data and environmental conditions such as cloud cover, Beaufort sea state and swell height. Photographs were taken with Canon EOS 50D, and EOS 7D Mark II digital cameras equipped with a 400 mm zoom lens and frame numbers corresponding to fluke or dorsal fin identification of individuals were recorded. It was beyond the scope of the survey to process the spinner dolphin dorsal fin and sperm whale (*Physeter macrocephalus*) fluke images for matches however this is intended for future work.

Hydrophone recordings during the 2013 small boat work were non-systematic and made using a hand deployed HTI MIN 96 hydrophone with 15 m cable and Zoom H4N digital recorder deployed into the water next to the boat while it was stationary. Experienced observers listened in real time and determined if cetaceans were heard or not by the presence of audible odontocete echolocation clicks or whistles. If cetaceans were heard, a recording was made sampled at a rate of 44.1 kHz, lasting 5–15 min and stored as a .wav file. Recordings have not been analysed for delphinid species identification at time of writing however sperm whale codas from the recordings are being included in The Global Coda Repertoire Project (S. Gero *et al.* unpubl. data) describing the geographic extent of sperm whale vocal clans.

Biopsy samples were collected with a PAXARM rifle system and dolphin cutting heads (5 mm × 7 mm) (Krützen *et al.* 2002), (New Zealand Department of Conservation permit HO-2990-03; University of Auckland Animal Ethics approval 000908) during small boat surveys around Palau's main island and southern lagoon. Samples were stored in Allprotect Tissue Reagent solution until their process at the University of Auckland. DNA was extracted from a small portion of the skin sample using a standard protocol (as modified by Baker *et al.* (1993)). The sex of all sampled animals was identified by amplification of sex-specific markers following Gilson *et al.* (1998). Amplification and sequencing of part of the mitochondrial DNA (mtDNA) control region (~800 base pair (bp)) was performed as described elsewhere (Olavarría *et al.* 2007).

Visual and acoustic survey of the Southwest Islands 2019

The 2019 visual and acoustic survey was conducted from 5 to 17 April from an opportunistic expedition tourism vessel; the 96-feet (29 m), steel-hulled live-aboard motor yacht, The Ocean Hunter III. As the itinerary was centred on tourism activity during the day, most of the acoustic survey effort was conducted while transiting at night. Though the survey was neither randomised nor systematic, the observers followed line transect methodology (Buckland *et al.* 2001) during daylight transit periods, with visual observers scanning for cetaceans using naked eye and binoculars from the 5.2-m high deck of the survey vessel. When cetaceans were encountered, the position, sightings cue, behaviour, estimated distance, group size, and direction of travel of the animal(s) were noted, and photo ID images were taken where possible.

Visual observations were supplemented with passive acoustic recordings that were collected using a towed recording system consisting of a SoundTrap ST4300 four-channel recorder and two HTI-96-MIN/3V/Low Noise (−165 dB sensitivity with a 1 kHz high-pass filter) hydrophones spaced 0.5 m apart in a 1-m long clear polycarbonate housing attached to a 200 m long dyneema tow line. Prior to each deployment, the SoundTrap was configured using SoundTrap Host software. Two-channel files were recorded. Each file was 2 min long and the sample rate was 288 kHz. The files were recorded internally to the unit and were downloaded to a laptop after each deployment. Files were reviewed for recording issues and spot checked for cetaceans. Post-processing of the files was performed using Triton Software employing the same methods as in the 2012 survey.

Anecdotal sightings and records

A bibliographic review of cetacean records was conducted from published literature for Palau and Micronesia. Building on anecdotal sighting information collected by interviews (Andrews 2010), additional reviews of local records of cetacean sightings and strandings were conducted with the assistance of the Palau Bureau of Marine Resources in 2013, as well as in person interviews with fishers, tourism operators and local biologists using a cetacean identification card and map of Palau to confirm location and likely species following the protocol used in 2010. The reviews described here include records of species that the authors were able to confirm through photographic evidence. These records are categorised as 'presence confirmed' in the species inventory, even though they were not observed during scientific survey efforts. For anecdotal records where photography was not provided, the species has been categorised as 'presence likely' in the inventory.

Results

Cetacean watching feasibility study 2010

A total of 30 h of observation effort was spent over five operational days between 7 and 17 July, 2010 on platforms of opportunity provided by local tourism operators during their normal operating hours. The focus of the voyages was diving tourism and as such the distribution of sightings effort was limited to the transit between Koror and popular dive sites along the south and west barrier reef and Peleliu Island, with sighting effort both underway and when the boat was stopped or moored to facilitate divers. Spinner dolphins were sighted on one day out of five from boat-based observations. Spinner dolphins and bottlenose dolphins (*Tursiops truncatus*) were seen from one helicopter flight. Combining opportunistic survey sightings with the anecdotal sightings from stakeholder interviews indicated the likely presence of 13 species of cetaceans in the Palau Territorial Sea and raised the profile of cetacean presence and status in the country amongst decision makers (Andrews 2010). The interviews and field observations also confirmed that cetaceans are not usually present in the shallow lagoon areas of Palau coastal waters and most commonly occur adjacent to the barrier reef. Anecdotal cetacean sighting maps representing community knowledge of cetacean distribution were used to identify potential hotspot areas for further investigation.

Line transect surveys 2012

The vessel-based line transect survey resulted in 45 sightings (Fig. 2) of a total of 756 cetaceans over a combined search effort of 155 h, covering a distance of 559.5 km. Transit times from anchorage to the survey area in addition to some inclement weather resulted in nine survey days over 13 vessel days during daylight hours. Experienced observers confirmed the presence of five species of cetaceans. Species detected included pygmy killer whales (*Feresa attenuata*), melon-headed whales (*Peponocephala electra*), sperm whales, spinner dolphins, and pantropical spotted dolphins (*Stenella attenuata*). Most visual cetacean observations were within 1 nm of the barrier reef or rock islands. Sperm whales were only observed in the East Strata. Pygmy killer whales, melon-headed whales and pan tropical spotted dolphins were only seen in the West Strata between Ulong Bay and Angaur Island.

Passive acoustic monitoring 2012

The towed array system was deployed on seven and a half out of the nine (83%) surveyable days at sea for a total of 48.4 h of recordings. Twenty eight unique acoustic events were identified from the LTSAs generated from the recordings. Of this total, 11 (39.3%) were classified as five different species using both acoustic and visual validation. These species include sperm whales, spinner dolphins, pantropical spotted dolphins, melon-headed whales, and pygmy killer whales. Unclassified acoustic detections were placed into one of three categories: unidentifiable odontocete, unidentifiable delphinid, and unidentifiable blackfish; the latter category is made up of six species of delphinids including killer whales, false killer whales (*Pseudorca crassidens*), pygmy killer whales, melon-headed whales and two species of pilot whales. Sperm whale codas were recorded for the first time in Palau and included in a Pacific-wide vocal repertoire analysis conducted by Hersh *et al.* (2022).

Aerial surveys 2013

The aerial surveys conducted in 2013 resulted in 18 separate cetacean sightings. Three species of cetaceans were confirmed by photography: spinner dolphins, spotted dolphins and false killer whales. There were additional sightings of unidentified delphinids, 'likely' melon-headed whales, and unidentified beaked whales (Fig. 3). There were no sightings in the northern strata, despite small cetaceans and sperm whales having been sighted in the area during the small boat surveys. This is likely due to sighting conditions which were Beaufort sea state 3–4 for 30% of the survey effort. Of the sightings in the southern strata, eight correlated to the south-western edge of the Barrier reef a between Ulong Bay and Peleliu Island, west of the World Heritage listed Rock Islands Southern Lagoon, thus further confirming this area as a 'hot spot'.

Small boat surveys 2013

Small boat work was conducted in 'hot spot' areas identified from the 2012 line transect survey and anecdotal sightings, with the aim of acquiring tissue samples for genetic analysis and acoustic recordings as well as photographs for identification catalogues of cetaceans (Hammond *et al.* 1990). This resulted in 16 sightings of three species of cetaceans: short-finned pilot whales, spinner dolphins and sperm whales over combined search effort of 48 h; roughly 6 h per day over 8 days, covering a linear distance of 397.4 km (Fig. 4). Acoustic samples from the 2013 surveys were distributed throughout the survey area. Unidentified odontocetes were heard on 18 of the 21 acoustic samples, generating an acoustic encounter rate of 85% based on spatial distribution (Fig. 4).

Encounter rates

Linear Encounter Rates (LERs) on transects during the 2012 vessel survey, transects during the 2013 aerial survey, and non-systematic vessel tracks of 2013 small boat surveys are in Table 1. Sightings of spinner dolphins occurred on all surveys; thus, this species had the highest LER for each

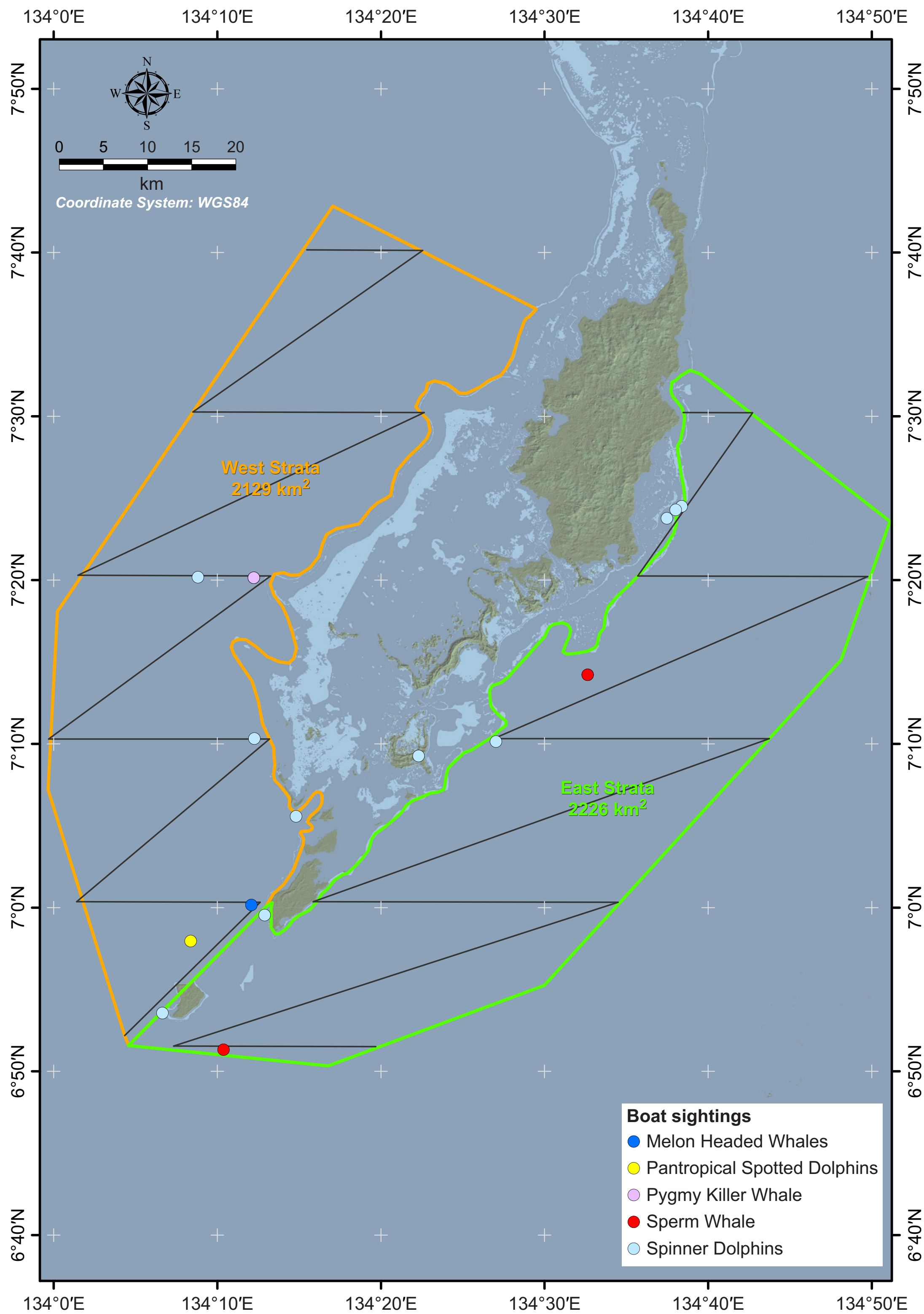

Fig. 2. Cetacean sightings during the 2012 line transect survey.

survey and overall, as would be expected, LERs for all species combined were higher for vessel surveys than the aerial survey, and higher for non-systematic vessel surveys (2013) than systematic (2012). These results also infer species' ecological preferences as spinner dolphins are predominantly coastal species, however lower LERs of other species (e.g.

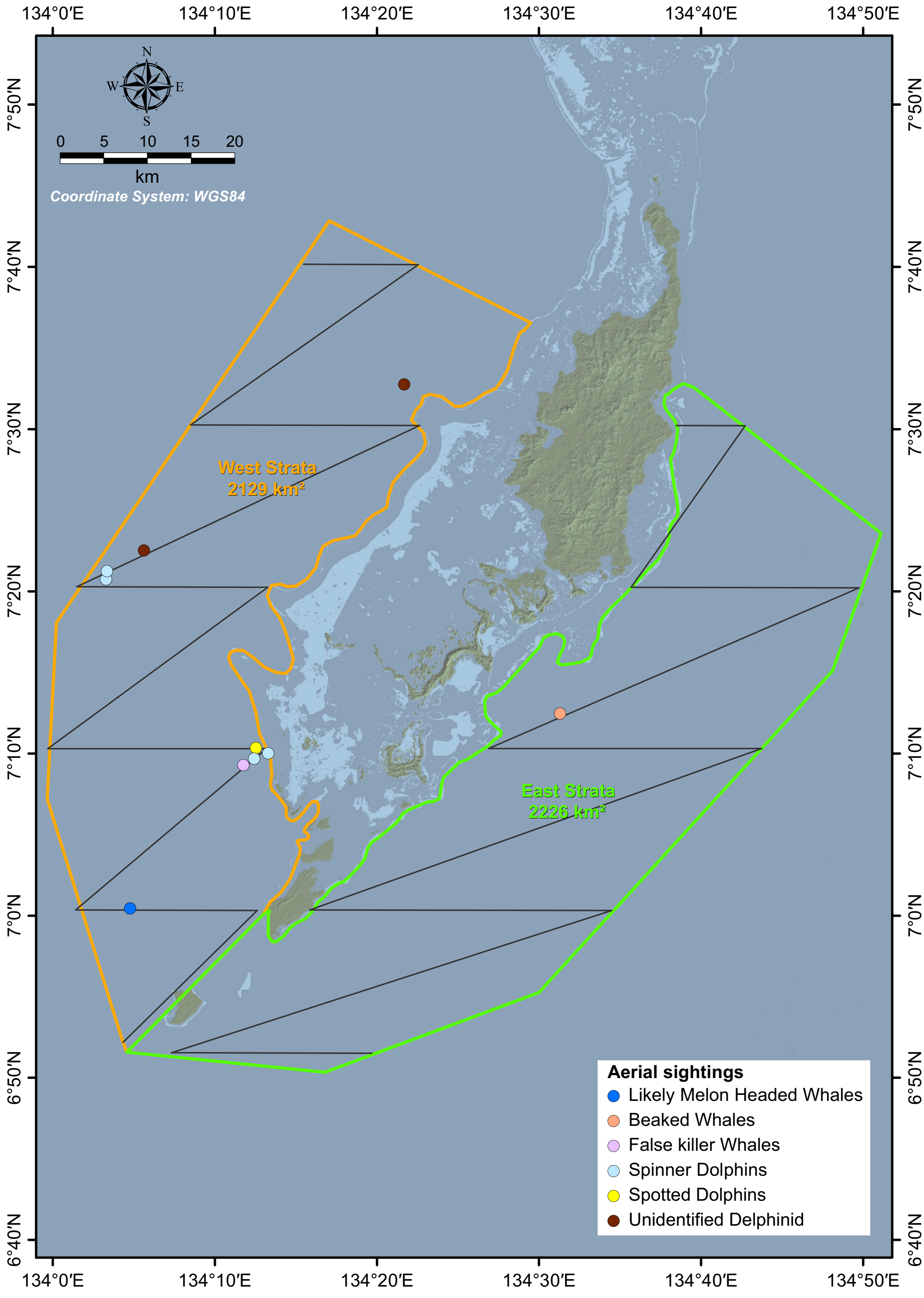

Fig. 3. Cetacean sightings during the 2013 aerial line transect surveys.

sperm whales) reflect their more typical pelagic distributions. Though LERs are not directly comparable between vessel and aerial platforms due to different speeds, our intent is to compare LERs among species within a year/platform.

Genetic sampling 2013

Nine tissue samples were successfully collected from a total of four sperm whales, four spinner dolphins and one pilot whale.

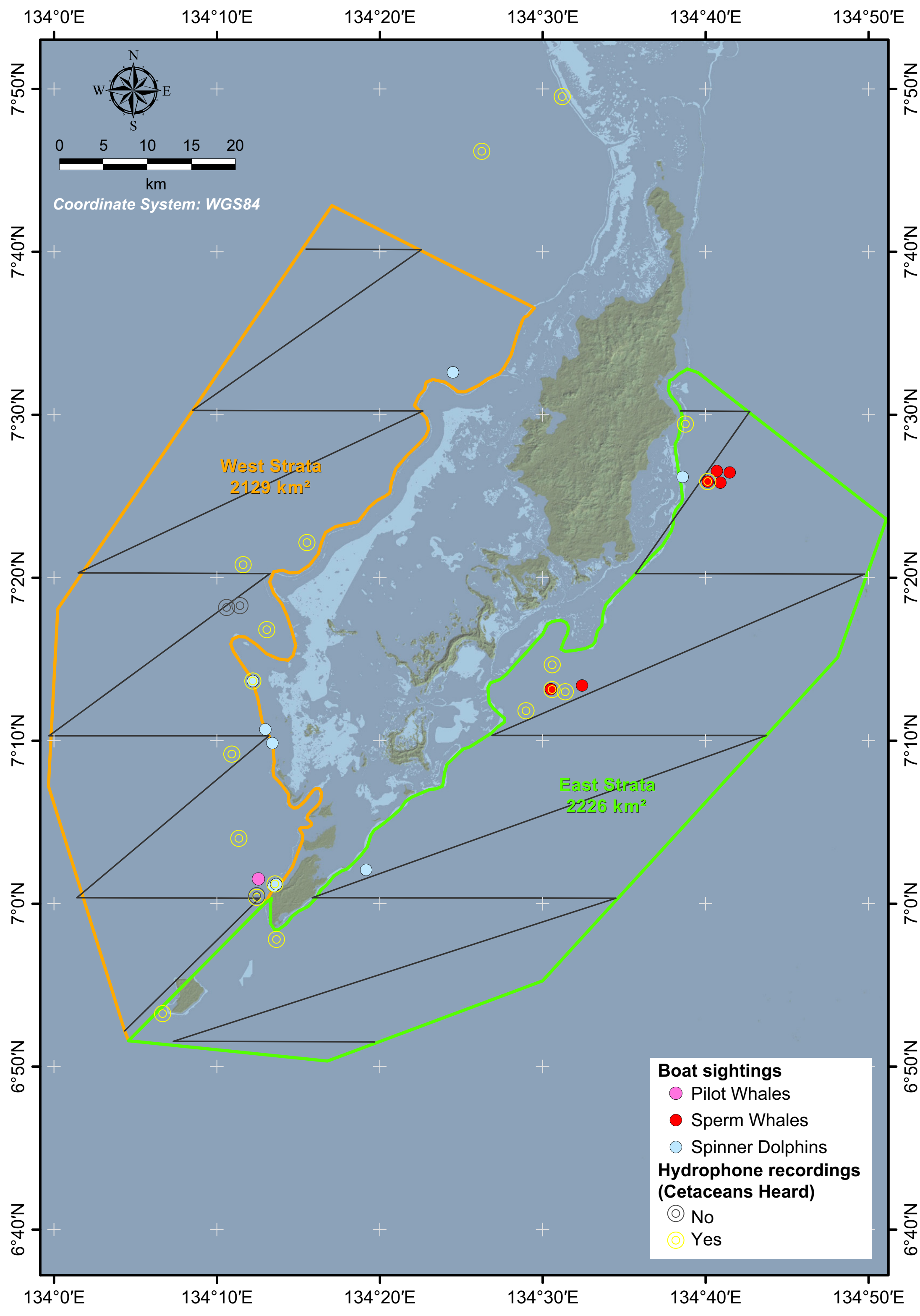

Fig. 4. Combined sightings and acoustic detections of cetaceans during the 2013 small boat surveys.

Genetic analysis confirmed all the sperm whales were female. In addition to the tissue samples collected from free ranging live animals, three samples were collected from unidentified cetacean bones (two large whale bones and one dolphin bone) that were donated for sampling from the local community after publicity in the local newspaper during the survey

Table 1. Mean on-effort Linear Encounter Rates (LERs) of confirmed species from vessel-based and aerial surveys of Palau coastal waters in 2012/2013.

Species	2012 vessel survey	2013 vessel survey	2013 aerial survey	Combined 2012/2013 vessel surveys
Spinner dolphins	0.225	0.395	0.139	0.296
Melon-headed whales	0.089			
Pilot whales		0.075		
Sperm whales	0.002	0.065		0.028
Pygmy killer whales	0.021			
False killer whales			0.054	
Pantropical spotted dolphins	0.045		0.018	
Unidentified delphinids	0.002		0.011	
Unidentified beaked whales			0.004	
All cetacean species combined	0.384	0.536	0.225	0.447

period. The dolphin bone sample came from a full skeleton of a recently stranded striped dolphin (*Stenella coeruleoalba*) (confirmed by photography) donated to the Etpison Museum. Bone samples have not yet been processed for genetic identification, however future surveys can build on this work and once additional samples are acquired, analysis of population structure can be carried out.

Photo identification

Of the 17 sperm whales sighted during the 2013 field season, dorsal identification photos were collected from 12 individuals and fluke IDs from two individuals. The fluke IDs have been entered into Happywhale matching platform (Cheeseman *et al.* 2017) with no matches returned. Nine of the animals were observed in a resting line together and were then resighted 5 days later in approximately the same position resting at the surface. This within-season resighting provides a basis for future investigation into the potential residency of sperm whales in Palau Trench. A further two fluke IDs and five dorsal IDs from 2011 were contributed by one of the local tourism operators and no matches were found within the years 2011, 2012 or 2013. Dorsal fin photo IDs were also collected from pilot whales, melon headed whales, and approximately 300 spinner dolphins. Although these have not been analysed for resighting's, several individual spinner dolphins with very distinctive dorsal fins were resighted in the field in the same area. As sample size for all species increases, these encounter histories of individually recognisable cetaceans can be used to estimate abundance, movements and site fidelity, migratory destinations, and reproductive rates (Hammond *et al.* 1990).

Preliminary density estimates

The study design and survey protocols were designed to generate tentative abundance estimates, however the sample sizes for on-effort, on-transect sightings from both the aerial (n = 10) and ship-based (n = 14) surveys were too small to generate robust estimates.

Without enough sightings to fit reliable detection functions, the data could not be used to provide accurate or precise estimates of abundance. However, as spinner dolphins were the most frequently sighted cetacean and are of the most import in terms of tourism implications for Palau, we conducted exploratory analyses for this species in the program Distance (ver. 6.2, see overview in Thomas *et al.* 2010). There was approximately equal support from the data for a hazard rate, half-normal, and a uniform detection function with a truncation distance of 200 m. Put another way, there was insufficient statistical power to differentiate among these three detection functions. The three models produced point estimates of abundance ranging from 1500 to 1700 spinner dolphins, but the coefficients of variation were large (58–77%) and the confidence intervals on the half-normal model were ~500,6, 100. It seems reasonable to conclude that there were at least several hundred spinner dolphins in the survey region at the time of the survey.

Visual and acoustic surveys of the Southwest Islands 2019

Visual survey effort totalled 30.78 h (25.7%) over a 5-day period. During on-effort periods, a total of five cetacean sightings were recorded which included 39 total individuals. Four of the five sightings were recorded as unidentified balaenopterid. The fifth sighting was a pod of spinner dolphins seen outside the channel of Helen Reef lagoon, thereby confirming the distribution of the species across Palau's EEZ.

Acoustic survey efforts totalled 79.28 h during a 7-day period (47.2%). Due to the limitation of the itinerary and the necessity to stay within the inner lagoon of Palau's main island group, surveying occurred on only seven out of 13 days. Acoustic survey efforts were restricted to transit periods in deep water so that the equipment would not become tangled in the reef.

Of the 79.28 h on effort, 20.95 h included acoustic events with cetaceans. There was a total of 44 unique acoustic events. Of the 44 acoustic encounters, 37 were classified as unidentified dolphin species, six were classified as possible blackfish, and one was classified as a possible sperm whale. Possible blackfish were categorised due to low frequency (<10 kHz), flat whistles seen within the spectrogram of the .wav files analysed (Oswald *et al.* 2007). The possible sperm whale encounter was categorised by distinctive lower frequency echolocation clicks with energy extending to ~20 kHz. No acoustic events overlapped with visual observations on this survey.

Discussion

Science-enabling partnerships

In 2012 and 2013, Whales Alive, in partnership with Sustainable Decisions and the Palau Government Bureau of Marine Resources, undertook the first dedicated investigation into the status of cetaceans in the Republic of Palau. The objectives of this investigation were to develop a cetacean species inventory for the territorial seas of Palau, identify areas of high cetacean density in Palau's coastal waters, generate species and habitat information to inform management and conservation goals of the Palau Whale Sanctuary, and inform management of the growth and sustainability of whale and dolphin watching tourism in Palau.

During the survey period, the research team worked closely with local stakeholders to deliver training workshops to build local capacity and expertise in the field of marine mammal research techniques, marine mammal tourism best practice, and marine protected area management. These workshops functioned to educate the community about cetacean biology and conservation and to establish a baseline for ongoing monitoring of cetaceans in Palau.

Survey effort was concentrated around the main islands of Palau, thus leaving the Southwest Island States of Sonsorol and Hatohobei data deficient with regard to the occurrence of cetaceans. In 2019, a private sector partnership between Conservation International and Cheeseman's Ecology Safaris supported the delivery of a scientific tourism voyage with the aim of providing conservation and livelihood benefits to the isolated Southwest Island communities. The science conducted on the opportunistic tourism platform established a baseline to fill information gaps with the aim of increasing effective management and conservation of these climate vulnerable islands.

The partnerships between the Palau Government, local and international NGOs, scientists and the private sector enabled the new information presented herein to be obtained. The importance of partnerships as a method to implement scientific surveys in remote locations, which are expensive and logistically difficult, cannot be overlooked.

Cetacean species occurrence

The Micronesia region is data-poor regarding the presence of cetaceans. Eldredge (2003) describes 13 species present in the waters of Guam, to the north of Palau, including 10 species of odontocetes and three species of mysticete, including sei whales (*Balaenoptera borealis*), which have not been described elsewhere in the region. Further surveys of Guam and the Northern Marianas Islands by Fulling *et al.* (2011) also confirm 13 species with sperm whales being the most frequently sighted along with sei and Bryde's (*Balaenoptera edeni*) whales. Hill *et al.* (2020) observed or acoustically detected 20 species in the Mariana Archipelago over a 9-year period adding Longman's beaked whale (*Indopacetus pacificus*), blue whales (*Balaenoptera musculus*), and fin whales (*Balenoptera physalus*) to what is known to occur in the region. Dalebout *et al.* (2008) identified a gingko-toothed beaked whale (*Mesoplodon ginkodens*) using genetic markers from an animal bycaught in a long-line fishery near Pohnpei, Federated States of Micronesia (FSM). Buden and Bourgoin (2018) describe a stranding event in FSM of *Kogia* sp. and note the occurrence of killer whales (*Orcinus orca*), false killer whales and short-finned pilot whales.

Historically, Palau's cetacean species inventory has consisted of anecdotal sightings reports and cetacean stranding events. Killer whales have been photographed in April 1993 (Rock 1993, cited in Reeves *et al.* 1999) and further reported by (Iwashita *et al.* 1963; Reeves *et al.* 1999), as well as through community consultations that identified the presence of both killer whales and sperm whales (PCS 2003). Their presence is further supported by community members' anecdotes about manta rays (*Mobula* sp.) disappearing from dive sites when killer whales come through. This species appears to be vagrant but is likely seasonally occurring when preferred prey, reportedly manta rays, are in breeding condition. This is consistent with documented killer whale predation on sting rays in New Zealand and other countries (Visser 1999).

Small, toothed whales of the blackfish group have been well documented. There are stranding records of melon-headed whales on the Palau coast (Donaldson 1983). Indeed, these animals are almost certainly resident in Palau waters, feeding diurnally offshore during the night and resting near shore during the day. This is the observed behaviour pattern of the animals in Palau and has been well described for the species in most island habitats where they have been studied (Baird *et al.* 2010; Silberg *et al.* 2011; Aschettino *et al.* 2012), and where they have displayed high site fidelity. Eldredge (1991) describes dated records of false killer whales and pantropical spotted dolphins, both also documented on scientific effort during our aerial surveys. Anecdotal reports have also documented short-finned pilot whales (Reeves *et al.* 1999), which were confirmed during the 2013 small boat surveys, and striped dolphins (Miyazaki and Wada 1978) in Palau waters, which are confirmed by a stranding event photographed more recently by a local tourism operator

(M. Etpison, pers. comm.). Eldridge further summarises reports of Fraser's, Risso's and spinner dolphins, as well as Cuvier's beaked whales (*Ziphius cavirostris*) that appear to be within Palau's EEZ. Andrews (2010) interviewed over 30 marine community members, including fishers and marine tourism operators, from which it became clear that local records of pilot whales were in fact sightings of multiple blackfish species, including melon-headed whales, pygmy killer whales and false killer whales, all of which were confirmed during the vessel-based visual and acoustic line-transect survey in 2012.

A pod of four beaked whales was sighted during the aerial survey in the south-east of the southern strata; however, it was not possible to confirm species. The observer recorded that the melon and rostrum were light grey while the body was dark grey with cookie cutter shark bite marks. Photography shows the body but not the head. From what is known of their distribution and distinguishing features (Reeves *et al.* 2002), and earlier records of this species (Eldredge 1991), it is possible that the sighting was of Cuvier's beaked whales, which are the most widely distributed of the ziphiids and have been recorded in Guam. Anecdotal sightings verified by photography have also confirmed the presence of Blainville's beaked whale (*Mesoplodon densirostris*) (Ron Leidich, pers. comm. 2014). Leidich also described an encounter with a small 'blackfish-like' whale that released a cloud of dark inky substance when startled at a close boat approach. This description likely describes one of the two *Kogia* species.

Townsend (1935) describes distribution of sperm whales from whaling logbooks (1761–1920) that showed sperm whales to occur in the southern extent of Palau's EEZ. Confirmed sightings of sperm whales place them in Palau year-round, which is consistent with what is known of female sperm whales remaining in low latitudes (Jaquet *et al.* 1996). Our finding that all tissue biopsy samples came from female sperm whales offers further support to this conclusion. These female pods are likely to show site fidelity in the Palau Trench, particularly in areas with submarine canyons and ridges where upwelling-associated primary productivity can be a proxy for sperm whale occurrence, and slope is an important environmental factor influencing sperm whale distribution (Pirotta *et al.* 2011). Site fidelity at the level of individual and clan should be corroborated with more targeted research, using photo ID, genetic, and acoustic methods.

Recent analysis by Hersh *et al.* (2022) found that seven sperm whale cultural clans in the Pacific Ocean have varying and overlapping geographic distributions. Their study reveals, for the first time, that trends in identity coda usage by sperm whale clans mirror trends in ethnic group marker usage by humans, highlighting the significance of cultural transmission and learning in the evolution of sperm whales and providing strong quantitative evidence that behavioural traits can have a cultural identification function in non-human species.

Moreover, the study unveiled previously unknown cultural information about Palau sperm whales through identification of their clan identity, based on recordings from the 2012 line transect survey. Of note, Hersh *et al.* (2022) assigned the coda repertoire from Palau to the Four-Plus clan with low certainty. This uncertainty may indicate that the Palau whales truly belong to the Four-Plus clan but were not recorded on a day when they were producing a significant number of identity codas. Alternatively, they may belong to a different clan, either one of the other six known clans in the Pacific or a new, as-yet-uncharacterised clan. Palau sperm whales also showed relatedness to Short clan and Slow Increasing clan, highlighting that the Palau whales are a cultural uncertainty. The lack of certainty regarding their clan makes it difficult to determine their proposed range. However, analysis of the available data suggests that the Palau whales belong to the Four-Plus clan, which has been observed in the Mariana Islands, Papua New Guinea, Tonga, Kiribati and South America.

A recent analysis by Vachon *et al.* (2022) of eastern Caribbean sperm whales showed that different geographically isolated sperm whale populations displayed culturally driven habitat partitioning, some showing high site fidelity and social organisation around specific islands. This challenges the traditional idea of sperm whales as ocean nomads and provides evidence that they can be island specialists. It is possible that Palau serves a similar function. Palau sperm whales' largely uncharacterised cultural status warrants further investigation to define the animals' distribution and cultural identity and, provides further motive for protection of the animals and their habitat.

Regarding mysticetes, whaling records appear to show that Bryde's whales occurred within the Palau EEZ in the 1980s (Perrin 2006). Sightings of Bryde's whales have also been confirmed by photography near offshore fish aggregating devices (FADS), which are deployed ~10 nautical miles off the coast (Etpison, pers. comm. 2013). The 2019 Southwest Islands voyage produced several sightings of unidentified mysticetes of 'Bryde's-like' description. Single blows were seen but no visible dorsal fin. The blows were not big enough to be larger rorquals, nor small enough to be a minke whale (*Balaenoptera acutorostrata*); Bryde's or Omura's whales (*Balaenoptera omurai*) appear the most likely fit to the observation. Recordings made near to the sightings were reviewed for baleen whale calls, but no calls were present.

Multiple community members have clearly identified humpback whales (by the distinguishing long pectoral fins); however, there is no photographic evidence for these records. It is possible that Palau represents the equatorial extent of the breeding migration of the lesser-known Western North Pacific population of humpback whales, most of which breed in the Philippines and Ogasawara, Japan (Acebes *et al.* 2007; Nakagun *et al.* 2020). These sightings are worth further investigation, especially during the boreal winter months when the animals are known to be present. This is particularly important given the evolving work to identify discrete wintering aggregations of the population (Oleson *et al.* 2022).

Photographs of a baleen whale skeleton, 12 m in length, which is exhibited in the Etpison Museum, Koror, Palau were taken to measure the dorsal area of the nasal, ascending process, frontal, interparietal and supraoccipital bones. Pictures of the stranding event of this animal do not clearly show three rostral ridges of a Bryde's whale (which is the collector's identification). The premaxila is not visible and the ascending process is quite wide in its posterior side, which should be diagnostic of Omura's whale as described by Wada *et al.* (2003) and Yamada (2008). Photographs were sent to Tadasu Yamada at Tokyo National Science Museum for species confirmation, who confirmed it is most likely the skeleton of Omura's whale (T. K. Yamada, pers. comm.); however, this is unconfirmed by genetics as no bone or baleen sample was able to be taken. If it is Omura's whale, this would represent important information about the distribution of one of the least known baleen whales. Given what is known of their distribution in the North Pacific (Cerchio *et al.* 2019) the occurrence in Palau is highly probable.

Here, we present a species inventory of cetaceans in Palau waters (Table 2) categorised into three groups: (1) 'Confirmed presence' – those documented on scientific survey efforts and other verified records; (2) 'Probable presence' – credible anecdotal records with clear species identification not supported by photography; and (3) 'Likely present' – based on species distribution information in the region suggested in Reeves *et al.* (1999) and undocumented records.

Table 2. Species inventory of cetaceans in Palau waters.

Number	Common name	Taxonomic name	Presence
1	Pygmy killer whale	*Feresa attenuata*	Confirmed
2	Melon-headed whale	*Peponocephala electra*	Confirmed
3	False killer whale	*Pseudorca crassidens*	Confirmed
4	Short-finned pilot whale	*Globicephala macrorhynchus*	Confirmed
5	Spinner dolphin	*Stenella longirostris*	Confirmed
6	Pantropical spotted dolphin	*Stenella attenuata*	Confirmed
7	Sperm whale	*Physeter macrocephalus*	Confirmed
8	Killer whale	*Orcinus orca*	Confirmed
9	Cuvier's beaked whale	*Ziphius cavirostris*	Confirmed
10	Striped dolphin	*Stenella coeruleoalba*	Confirmed
11	Risso's dolphin	*Grampus griseus*	Confirmed
12	Fraser's dolphin	*Lagenodelphis hosei*	Confirmed
13	Bryde's whale	*Balaenoptera edeni*	Confirmed
14	Blainville's beaked whale	*Mesoplodon densirostris*	Confirmed
15	Oceanic bottlenose dolphin	*Tursiops truncatus*	Confirmed
16	Omura's whale	*Balaenoptera omurai*	Probable
17	Pygmy sperm whale	*Kogia breviceps*	Probable
18	Dwarf sperm whale	*Kogia simus*	Probable
18	Humpback whale	*Megaptera novaeangliae*	Probable
19	Rough-toothed dolphin	*Steno bredanensis*	Likely
20	Longman's beaked whale	*Indopacetus pacificus*	Likely
21	Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	Likely

Cetacean hot spot areas

A total of 73% of all cetacean observations made in the first season of the project were within 1 nm of the barrier reef or rock islands, thus initial findings of the 2012 field season suggest that cetaceans favour the reef edge; this area likely features seasonal currents, upwellings and fish spawning events (PICRC 2007) that could imply food availability, in addition to shallow habitat for resting.

The aerial survey repeated the southern strata transects and included a new survey area to the north of the main islands. The southern strata were surveyed using a helicopter, which was an effective platform. However, due to the remoteness of the northern survey area, the helicopter was unable to refuel. Thus, a small twin-engine aircraft was used to survey the northern strata. Conditions on the day the northern strata were surveyed were marginal on the eastern coast, where sperm whales had been sighted previously. There were no sightings in the northern strata, even though we had encountered small cetaceans in the area during the non-systematic small boat work.

Of the sightings in the southern strata, eight sightings, which represented the largest cluster, were found off the south-western coast, thus confirming it as an area of high cetacean density warranting further investigation as a hot spot. The areas identified as having the highest clusters or sightings of cetaceans were the focus of the small boat work in the second field season. Cetacean observations from the small boat work in 2013 further confirmed that the south-western coast between Angaur and Ulong is an area of high cetacean density.

Cetacean occurrence in this area may be explained because the timing of the project in both 2012 (January–February) and 2013 (April) corresponds to the time of year when the trade winds blow from the northeast and thus, the area provides the most sheltered waters in Palau. Future research in alternate seasons when the trade winds are from the south-west should test the hypothesis that small cetaceans in particular favour the leeward side of the island, which for October would be the northeastern coast of Babelthaob. Spinner dolphin sightings were more widely distributed around the survey area, with most sightings being very close to the reef. In most observations, the spinner dolphins exhibited resting behaviour during the day, consistent with what is known of their night-time feeding habits on offshore diurnal cephalopods (Würsig *et al.* 1994).

All sightings of blackfish during the line transect and small boat surveys (melon-headed whales, pilot whales, false killer whales and pygmy killer whales) were on the western side of the islands in shallower water. Conversely, all sightings of sperm whales and beaked whales were off the eastern coast, roughly where ocean depth contours are from 1000–2000 m on the edge of the Palau trench (8000 m), which is consistent with sperm whale and beaked whale deep water habitat (Taylor *et al*. 2019). The majority of the sperm whale sightings and the beaked whale sighting were on the slope adjacent to the area described as 'short drop-off' basin by Colin (2009). This area has interesting bathymetrical canyon features, which appear to be a preferred habitat for the cryptic, deep-water species occurring in Palau and is thus a cetacean hotspot area suggested for further investigation.

Lessons learned from survey design and implementation

Efforts to conduct aerial surveys in 2012 were curtailed by a lack of availability of suitable aircraft. Instead, vessel-based visual and acoustic line-transect surveys were conducted together with photo ID of both on- and off-effort sightings. In 2013, two small aircraft were available. In order to survey a larger area, aerial surveys were thus conducted and combined with small vessel surveys in areas of higher cetacean density. The aerial survey provided greater access to the survey area, however the expense and unpredictability of availability of aircraft in Palau means it is not as viable for long-term replicable studies, in contrast to vessel-based line transect surveys. Moreover, conducting surveys in remote locations with limited resources, as is the case in Pacific Islands, makes robust data collection difficult due to different types of aircraft and vessels at slightly different speeds and heights with different observer visibility biases. There was also difficulty identifying species from aerial photography. The large live-aboard vessel provided an effective survey platform; however, slow speed meant long travel times to reach the survey area, thus requiring a higher time-based cost. The small boat was very fast and thus effective in reaching the survey area; however, it had limited height and thus hindered observer visibility, and was not considered safe for offshore transects. These limitations should be considered for future surveys.

Although the surveys did not generate enough sightings to report reliable abundance estimates, several factors must be kept in mind. First, a region may need to be surveyed several times before rare, or rarely sighted species are seen, or at least seen often enough to report a robust abundance estimate (Kaschner *et al*. 2012). As long as surveys follow good line transect protocols, survey data can be combined (e.g. using sighting platform as a covariate in the detection function) so that information on rare species can accumulate over time, and, these biodiversity surveys can progress from species inventories and studies of distribution to include estimates of abundance (Williams and Thomas 2007). We present a tentative abundance estimate for spinner dolphins for illustrative purposes only and recognise that it is of limited value for immediate management purposes or as a baseline for monitoring trends over time. Nonetheless, given the complete lack of information from the Palau region, we see value in noting that several hundred and possibly a few thousand spinner dolphins were found in Palau, albeit with large associated caveats. Given the increased focus on the monitoring of cetaceans to meet objectives of Palau National Marine Sanctuary (PNMS) and the Protected Area Network (PAN), the quantity and quality of data on cetacean species is likely to grow over time.

Conservation management

Before the 2012/2013 dedicated investigation was undertaken, most government, industry and community stakeholders believed that cetaceans largely did not occur in Palau, and that dolphins and pilot whales were the main species to be seen, albeit infrequently. Correspondingly, the stakeholders have been supportive and interested in the outcomes of the project. As such, species and habitat information generated from these surveys is of interest to the Bureau of Marine Resources (BMR), the Koror State Department of Conservation and Law Enforcement, the PNMS office, and PAN to inform management and conservation of cetaceans in Palau Marine Mammal Sanctuary. With better understanding of cetacean species diversity and density, the local authorities have a basis to monitor and conserve cetaceans in the PNMS; and a monitoring and management plan for the Sanctuary is in development. Cetacean sightings are reportedly being documented by government personnel as part of protected area monitoring and routine enforcement effort. The majority of cetacean sightings occur in Koror State waters and as such the State is very keen to partner further research efforts and conduct specialised training for their conservation and law enforcement officers and rangers.

In contrast to the domestic cultural values to conserve cetaceans, the Palau government, as a member of the International Whaling Commission (IWC), has a history of voting with whaling countries to block cetacean conservation at scale, in particular using their vote to block establishment of the South Pacific Whale Sanctuary at the International Whaling Commission in 2004. Strand and Tuman (2012) speculate that Palau's opposition to the South Pacific Whale Sanctuary came at the behest of Japan, a significant development aid donor to Palau. Japan announced its intention to leave the IWC in 2019, and this may alter any political cost of supporting whale sanctuaries. Given Palau's GDP is heavily reliant upon the tourism industry, the tourism potential of cetacean watching has in recent years inspired an alternative policy position.

Cetacean tourism development

Cetacean tourism is indeed feasible in Palau (Andrews 2010), moreover, it is hoped that species and habitat information generated from the surveys can inform the management and growth of whale and dolphin watching tourism in Palau. Many of Palau's States aspire to develop environmental tourism. There is much interest from community, government, and tourism stakeholders in the development of cetacean tourism; however, in keeping with Palau's conservation record and high standards of protected area management, the stakeholders largely agree that more research is necessary to provide better understanding of the conservation status of the animals and greater certainty to viewing opportunities. Furthermore, they recognise that marine mammal watching regulations need to be developed before a cetacean tourism industry evolves. Currently the size and height of the vessels used by marine tourism operators are appropriate for operational conditions in the lagoon and inshore reef areas. These vessels are not designed to go very far offshore, which may hinder potential for sperm whale watching in the deep water off the eastern coast, but they would be appropriate for use off the sheltered south-western coast where the majority of small cetacean sightings occur.

Though the 2012 survey encountered 45 sightings of cetaceans, the sightings were spread out over 155 h of search effort. The encounter rate of cetaceans may not yet be frequent enough for local tourism operators to reliably support dedicated whale watching trips; however, most operators encounter dolphins between dive sites. Further training of marine tourism operators in identifying cetaceans, and best-practice rules for whale and dolphin watching operations have been identified as priority next steps for the industry to grow. It is important to note that well-trained tourism operators, enforcement officers, fishers, and park rangers can also be a valuable resource in documenting threats to cetaceans, including entanglement in fishing gear or evidence of vessel strikes (Pace *et al.* 2014).

Capacity building

Concurrent to the 2012/2013 scientific surveys, the field researchers, in partnership with local government and NGO stakeholders, facilitated substantive developments in capacity building of local stakeholders to manage cetaceans through three national workshops.

A training workshop to build local capacity and expertise in the field of marine mammal research techniques was conducted successfully in January 2012. A marine mammal management workshop was held in February 2012 to inform members of state Government, Senators, tourism operators and researchers of survey outcomes with particular reference to the management of Palau's marine mammal sanctuary and the sustainable development of cetacean tourism.

In May 2013, a national marine mammal management workshop was held to discuss issues and options for a Plan of Management for Palau marine mammal sanctuary. The workshop achieved its aims to strengthen knowledge of participants with regards to cetacean research and issues for management, establish an agreed sightings/stranding/monitoring protocol for Palau, and agreed to establish a 'working group'. A summary of prioritised issues and research needs for the Palau Marine Mammal Sanctuary was established, as well as an agreed approach to initial monitoring of marine mammals in Palau's waters that is aligned with PAN and Micronesia Challenge monitoring.

Conclusion

Approaching a previously unsurveyed area from varied survey platforms, with volunteer staff, on a prohibitive budget to conduct science is always a challenge; however, through dedicated surveys and confirmed anecdotal sightings, scientific knowledge of cetacean species occurrence, distribution and density has been gained for Palau. The data collected in the surveys described here, however modest, represent an important step as Palau and other Pacific Island countries and territories tackle threats to cetaceans, such as bycatch and entanglement in fisheries, climate related habitat change, ocean noise, and ship strikes. Indeed, if replicated over time, data from surveys like this can give important information on average encounter rate by species, which can be used to explore how frequently the area would need to be monitored to be capable of detecting cetacean species decline of a given magnitude (Tyne *et al.* 2016).

This work was supported and partnered by many Palauan government and private sector partners whose immense cultural and local knowledge and experience underpinned its success. Species and habitat information resulting from this paper is designed to assist delivery of a monitoring and management plan for PNMS and the Palau Marine Mammal Sanctuary, and provide certainty to guide cetacean tourism development sustainably, advancing the conservation of cetaceans in Palau. The results presented herein further elevate the significance of understanding the status of cetaceans in Palau and the Micronesia region.

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