BEHAVIORAL OBSERVATIONS AND HABITAT USE OF DUGONGS (*DUGONG DUGON*) IN THE ROCK ISLANDS SOUTHERN LAGOON, PALAU

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GEF Small Grants Programme
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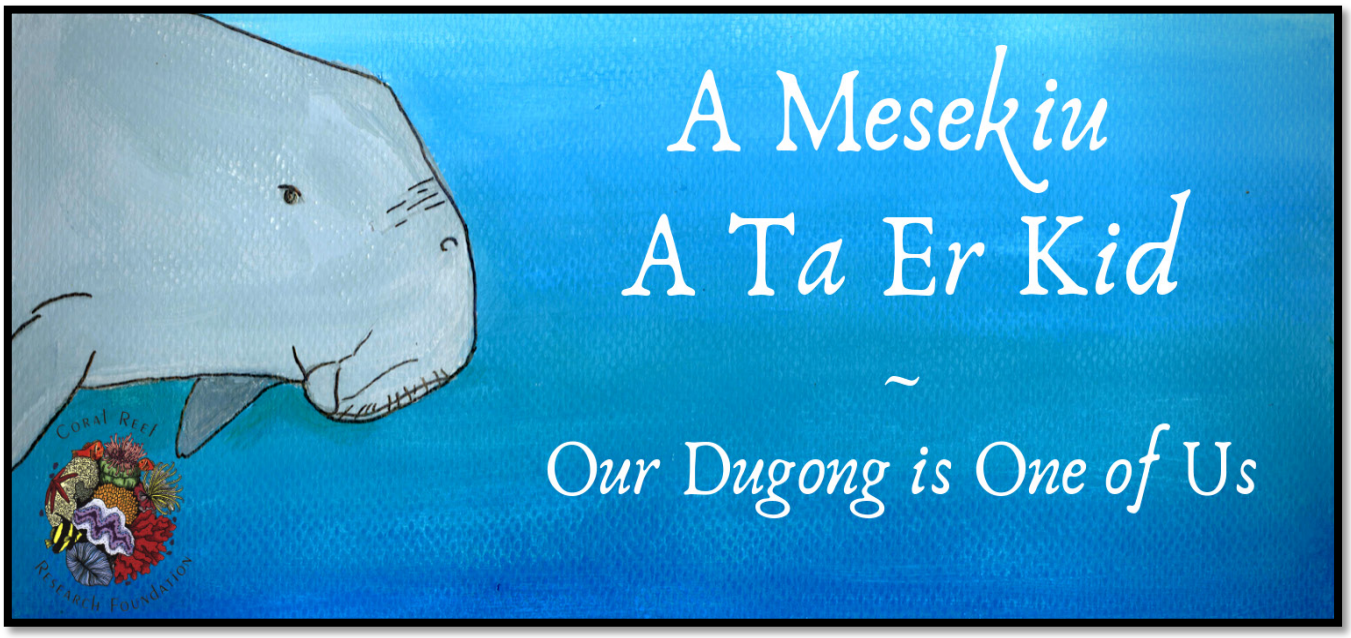

A. Project Objectives and Outputs:

The overarching objectives of the project were to:

I. Enhance scientific understanding of Palau's dugongs to support conservation efforts through non-invasive, cost-effective behavioral observations using consumer-level portable drones and underwater time-lapse cameras, and
II. Revive public awareness and support for dugong conservation among the Palauan community.

The dugong (*Dugong dugon*) is an iconic marine mammal considered threatened throughout nearly all of its range. The population in the Republic of Palau is the most isolated population in the world, and due to the dangers that the population could easily go extinct, Palau has been designated as an International marine Mammal Area for dugongs by the Marine Mammal Protected Area Task Force, the first such designation in Micronesia. Although the species is totally protected by law in Palau, illegal hunting and natural mortality continue to occur. The dugong is not a species which easily provides opportunities to learn about its life history, biology and genetics; all data are hard won through extensive effort and even the best information has many uncertainties. A matter seemingly as simple as determining, with a reasonable error, the number of dugong remaining in Palau has proven elusive, as the creature itself. The Coral Reef Research Foundation, along with the Etpison Museum, has spent the last ten years attempting to answer some of those questions and prepared several reports which add to the baseline information (eg. Brownell et al. 1981, Rathbun et al. 1988, Kitalong 2008) from which we can build our knowledge base. We have tested methods for examining the long term structure of the local dugong population in the Ngederrak Conservation Area, mostly from using aerial platforms and new technology. Our aim is to continually improve our understanding of this species, and improve our methods and protocols to refine knowledge of dugongs so they will continue to inhabit Palau's waters.

Objective 1: Advance scientific understanding of dugong behavior and habitat use in Palau, including migration patterns and presence/absence in relation to tidal height

Outputs delivered under Objective 1:

The direct behavioral observations of the occurrence of dugongs and their habitats at Ngederrak and Lighthouse Reefs in relation to environmental conditions (tides, currents, other) made using drones and underwater time-lapse cameras have significantly improved our scientific understanding of dugong presence/absence and migration patterns, as well as habitat use. Our work clearly identifies Ngederrak Conservation Area (NCA) as a very high priority area for dugong protection. The use of new and emerging technology and equipment also expanded our scientific toolkit and allowed us to develop and improve our skills using this technology to collect data. The results clearly show the benefits of using these tools and have provided new data which will be more accurate for use as baseline information for continued monitoring of their population status.

New Information on the Habitat of Ngederrak NCA and other dugong habitats

We decided to focus much of our effort on Ngederrak Reef, a protected area close to Koror which is known to be an important dugong feeding area (Fig. 1). The area is bounded on two sides by tidal channels (Ngel and Lighthouse channels), an inner side facing the Malakal lagoon and a seaward reef sloping from very shallow water down to about 70 m depth. The seaward reef is protected from major ocean swell and waves by another reef structure several km further seaward called Uchelbeluu

Reef, which results in Ngederrak reef having a zonation quite different from that found on typical east side barrier reefs in Palau (Colin 2009).

The area can be divided into reef habitat (stony coral and other benthic species typically found on coral reefs) and seagrass/sediment flat habitat. The seagrass dugong feeding areas are very shallow, becoming emergent on spring low tides, and hence are not accessible to dugongs when tides are low. This area is the shallowest part of the Ngederrak complex, and the southernmost corner of the protected area is the dominant area where dugong were most often seen.

Monitoring of Dugongs using Drones

Drone flights were primarily conducted by Palauan research assistant John Swords from 08:30 to 17:30 hrs. One to four flights were made during any given daily session, in which the drone was flown for a period (10-15 min) consistent with the battery power available, then landed, battery replaced and flown again at a later time. This allowed us to cover periods of up to several hours after the tide rose sufficiently for dugongs to go up into the shallows to feed.

The times when drone flights were made were not random. Due to limited numbers of flights, we tended to focus flight effort when we believed there was a high probability of having dugongs present on the shallow beds. Our data is therefore not compatible with certain types of analyses, but for assessing the relationships of dugong behavior with natural factors, such as the tide level, many conclusions can be drawn.

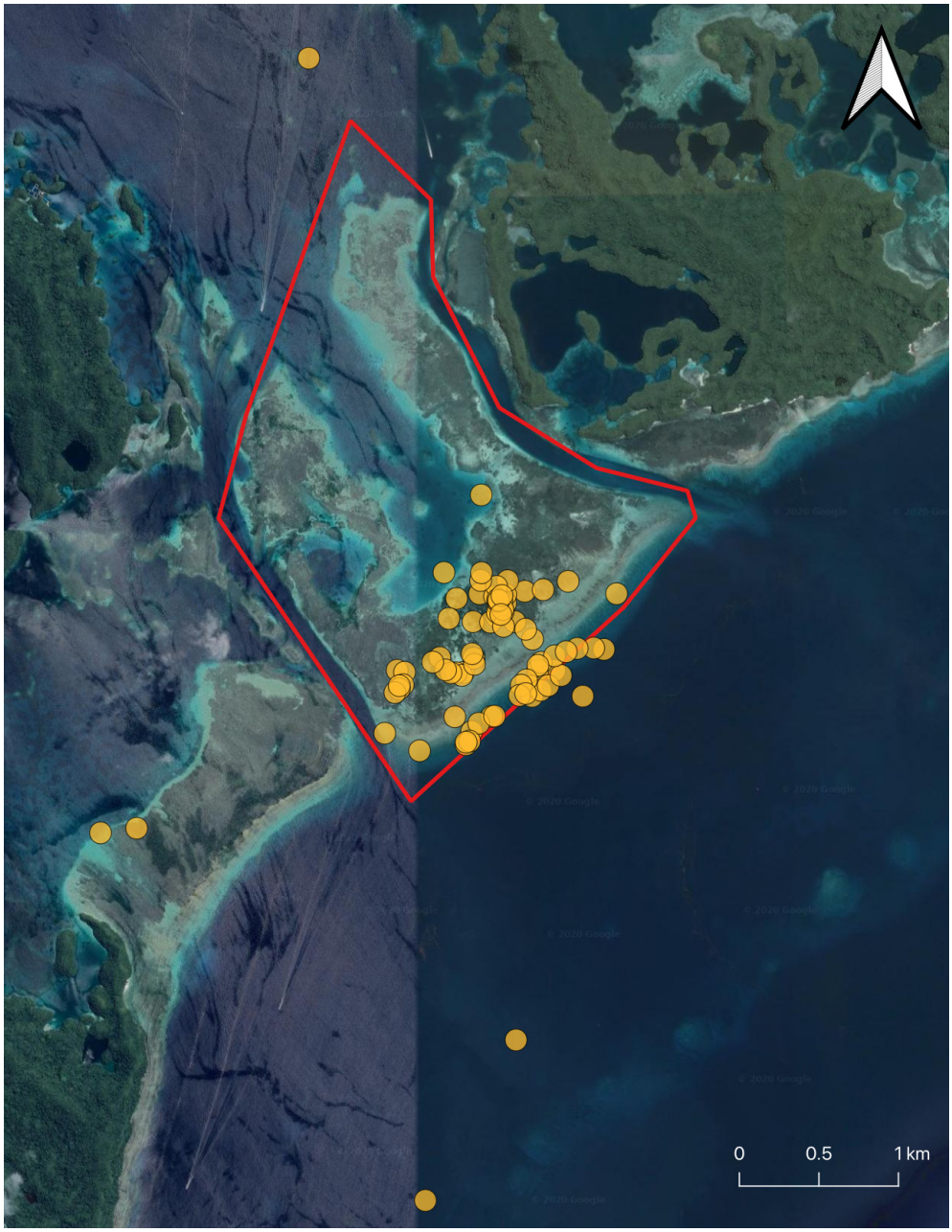

Figure 1: Map with each of the 83 locations where individuals or groups of dugongs were seen with the Ngederrak Conservation Area boundary shown in red. Dugongs were observed to exit the Conservation Area on each tidal cycle. Exiting over the reef front, where the majority of sightings were recorded, would provide greater safety than exiting via the channels on either side of Ngederrak or into Malakal Harbor, which have much higher boat traffic.

Numbers and Occurrence of Dugongs by Location

Data collection was very successful, with a total of 134 drone flights completed. Total flight distance covered was 539 km. Dugongs were observed on 55% (n= 74) of all flights and at 83 GPS locations, either as individuals or in groups (Fig. 1). Flight data were correlated with environmental data, particularly tide level, in tables used for further analysis. All tide data cited in this report are measurements of water level made hourly at the Malakal Tide Gauge, which is operated by the

University of Hawaii Sea Level Center (UHSLC). The station uses a tidal datum with relative values in mm. Hourly tide data, as well as details of the datum for the station, are available on the UHSLC website (https://uhslc.soest.hawaii.edu/).

Numbers of Dugongs Observed

We recorded 521 individual dugong sightings during our surveys. This total does not represent the absolute numbers of individuals present, or indicate a total population size, but rather totals the number of dugong seen on each day, summed for all days flights were made. Overall it was likely that many of the recorded dugongs were counted more than once, on multiple days, hence the absolute number of dugongs living in the Ngederrak area would be somewhat less. The vast majority of dugong sightings occurred within the Ngederrak MPA, where most of the flights were also conducted – of the 134 flights, 103 were focused on Ngederrak MPA (77%) while the remaining 31 flights (21%) occurred in adjacent areas, including Lighthouse reef and Malakal harbor. Of the 521 individual sightings, only 9 (<2%) were seen outside the Ngederrak Conservation Area and adjacent forereef (Fig. 1).

The largest herd observed comprised 59 dugongs (Fig. 2), with an average group size of 7 dugongs (n=92; median = 4). Figure 2 is a bubble plot of herd size, indicating that it was common to record group sizes of over 10 dugongs. This is an encouraging finding given the uncertainty around population numbers of Palau's dugongs. This new data on dugong occurrence, group sizes and numbers present from drone flights relative to GPS location takes the baseline information available on the populations to an enhanced level. From this information it is now feasible to repeat surveys with high precision/accuracy in the future. Previous surveys using fixed-wing aircraft or helicopters had too many biases and variables to be truly repeatable, but the wide spread use and low cost of aerial drones makes future repeat surveys easy and affordable.

Although our study did not explicitly set out to produce a population estimate or aim to identifying individuals/record re-sightings, the high numbers seen in a single group are supportive of the idea that the population has increased since the first recorded surveys in 1997/1978, or at the very worst is stable compared to the earlier data. From our data alone it is still not possible to confidently conclude that the population has indeed increased over time. Whole population surveys are difficult to standardize, but additionally, this was not the goal of our project. Results, however, are very encouraging because we encountered dugongs in over half (55%) of all drone flights and were able to record multiple sightings of herds with >10 individuals (Fig. 2). Our new data provides a useful baseline for potential follow-up studies with a more specific focus on estimating population status.

The promising nature of this finding is further supported by the relatively high sighting rate of calves (88 of 521 individuals, or 17%). This compares to historical numbers from multiple studies (Table 1), with the caveat that several different methods were use for earlier counts. In the absence of length measurements or need for a strict definition of what constitutes a dugong calf, we followed Brownell's (Brownell et al, 1981) relatively broad definition: "Smaller individuals that appeared to be in attendance with larger animals, presumably their mothers, were recorded as calves." Examples of individuals deemed to constitute calves are shown in Figure 3.

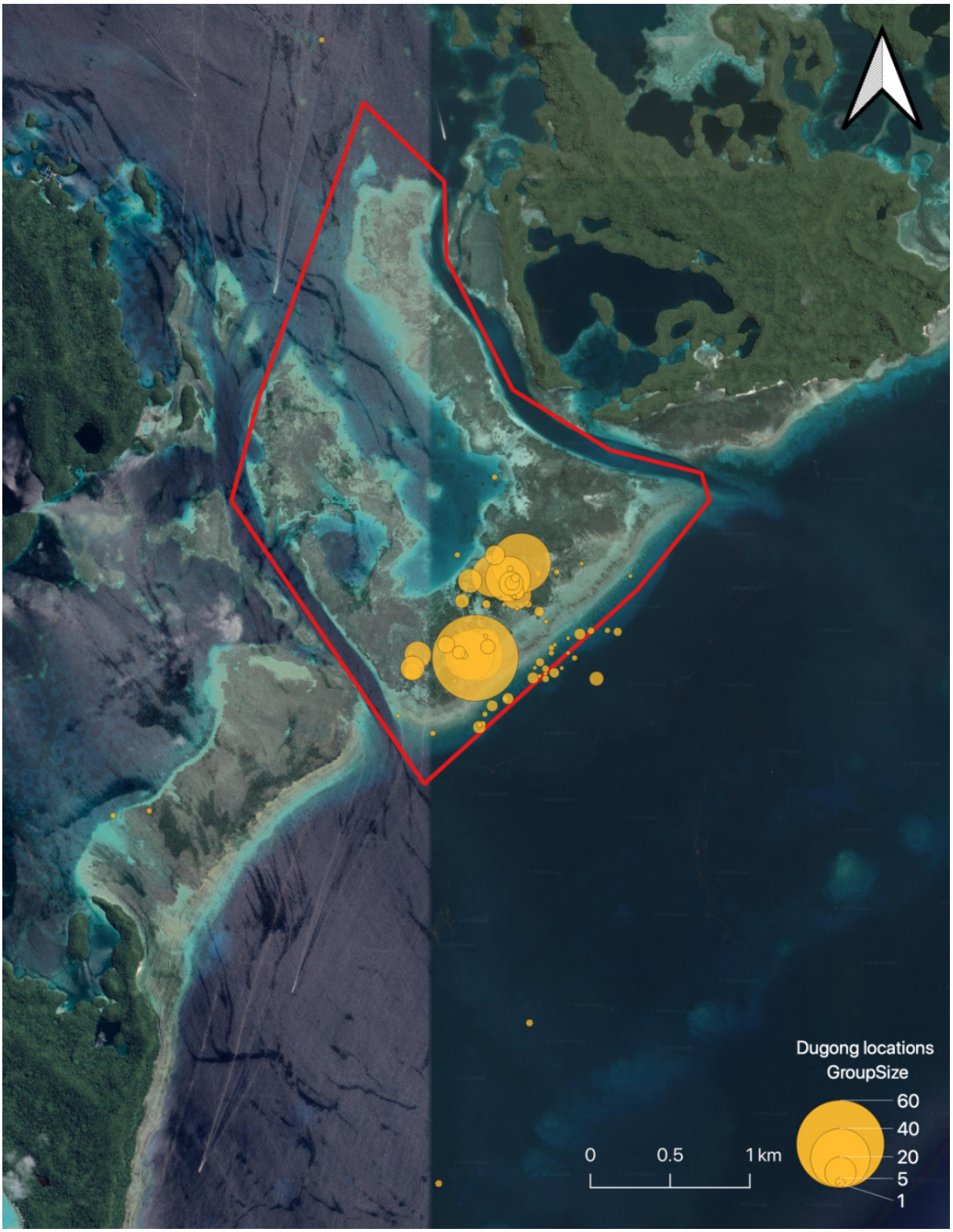

Figure 2: Map showing the location and number of dugongs recorded. Bubble size represents dugong group size, where the smallest bubbles represent a single dugong and the largest bubble size shows the herd of 59 individuals.

Year	Total Dugongs Observed	# of Calves	% Calves	Reference
1977	15	2	13%	Brownell et al, 1981
1978	34	8	24%	Brownell et al, 1981
1983	38	3	8%	Rathbun, et al 1988
1991	26	4	15%	Marsh et al 1994
1998	33	7	21%	Davis and Smith, 2004
2003	27	7	26%	Davis and Smith, 2004
2007	30	10	33%	Kitalong et al, 2008
2005-8**	58	9	16%	Kitalong et al, 2008
2009/10	912	53	6%	CRRF, 2012
2018/19	521	88	17%	This study

Table 1. Total number of dugongs and calves observed in aerial surveys in Palau using various methods from 1977 to 2019. **Numbers are from incidental sightings (2005-2008) from a boat or while fishing.

Tide levels and Dugong Occurrence: Relationships

Following specific individuals or groups of dugongs improved our understanding of the dugongs' habitat use patterns, particularly in relation to their migration patterns into and out of the Ngederrak Conservation Area and in synchrony with tidal height. Dugongs were observed to exit the Conservation Area on each tidal cycle. They left the area over the reef front (Fig. 4), which sees far less boat traffic than the channels on either side of Ngederrak or nearby Malakal Harbor.

We recorded six observations of dugongs leaving the reef-top seagrass beds (Fig. 4), five of which occurred over the fore reef and one into the deeper water of the lagoon within Ngederrak. There were three occasions where dugongs crossed over the fore reef during an outgoing tide, at tidal heights of 1630-1810 cm (Fig. 4), and two occasions when dugongs swam from the seagrass area to deeper water when the tide was still incoming. During these events, tide heights were over 2000 mm (2 m), so that the dugongs may have already had enough time to feed on the shallow seagrass beds. In addition, we recorded a dugong starting to enter the reef at the main entry and exit location (Fig. 4), but then make a turn and retreating to deeper water.

Our observations and drone flights occurred over 18 months, from April 2018 to October 2019 with positive observation records during all seasons, indicating no major changes in dugong occurrence with season. Other factors that might affect dugong occurrence in the broad scale are changes in mean sea level (MSL), which can vary as much as 600 mm over a few months caused by El

Niño/La Niña Pacific basin shifts. The state of MSL affects the amount of time shallow flats are sufficiently deep for dugong feeding and this subject is addressed later in this report.

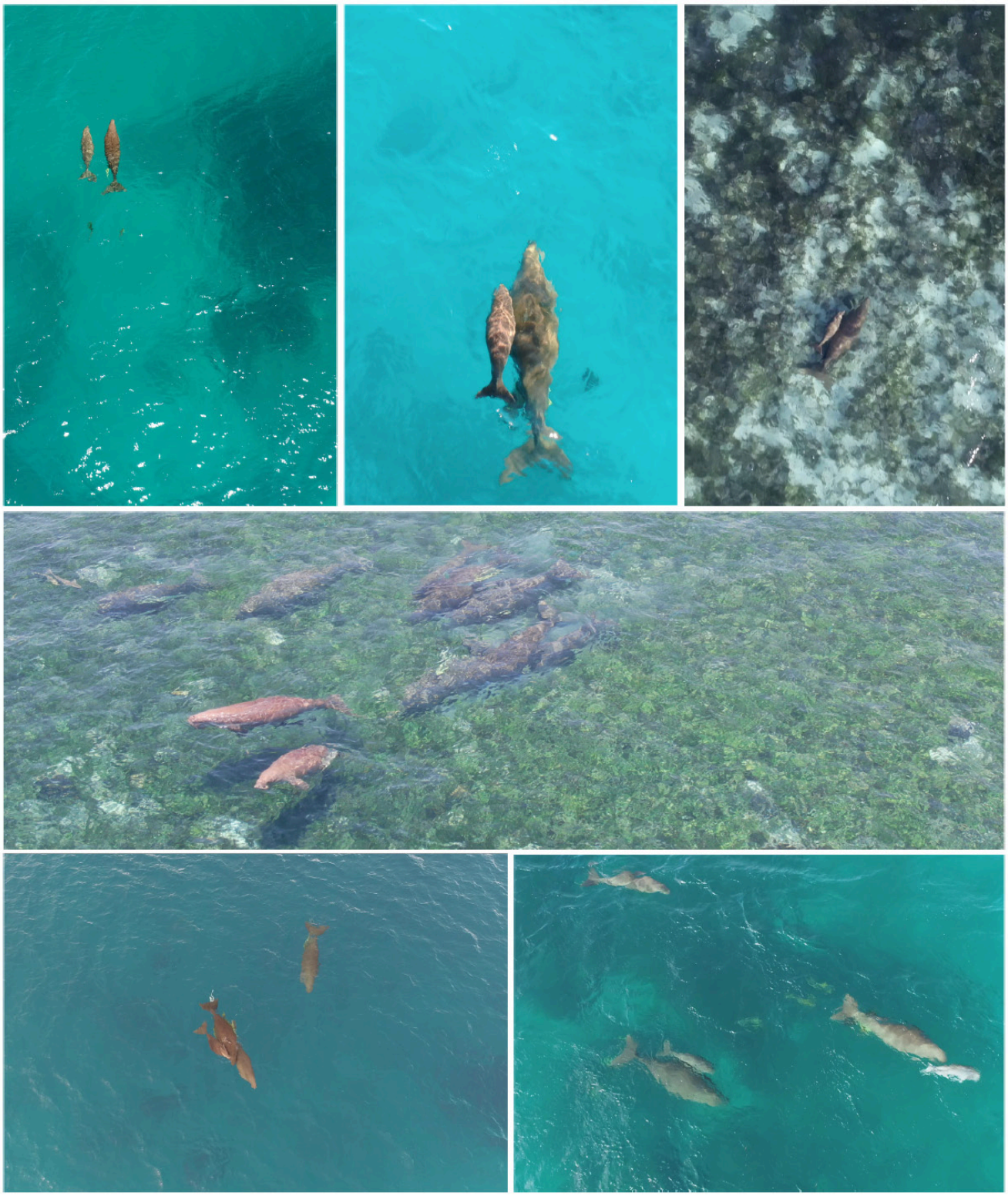

Figure 3: Examples of cow-calf pairs, either as solitary pairs or in a larger group, to illustrate which individuals were deemed calves for the purposes of this study.

Figure 4: Map showing the main migration paths of dugongs entering or exiting from the seagrass beds at Ngederrak Conservation Area, with associated tidal heights, during each crossing indicated.

Because Ngederrak reef/seagrass beds are overall a very shallow area, with the seagrass beds being the shallowest, the areas where dugong feed are limited by tidal height. To attempt to achieve some understanding of the relation between absolute water levels and access to the flats, we compared the presence/absence of dugongs on Ngederrak with tidal level. Occurrences of dugongs were recorded from drone flights, while water levels were from the tide data for Malakal. Drone flights were normally conducted when we thought the tides were sufficiently high to allow dugongs to swim onto the grass flats. Thus, our observations are biased towards periods we assumed would have positive observations. However, we did obtain data points at other tide levels, though fewer in number.

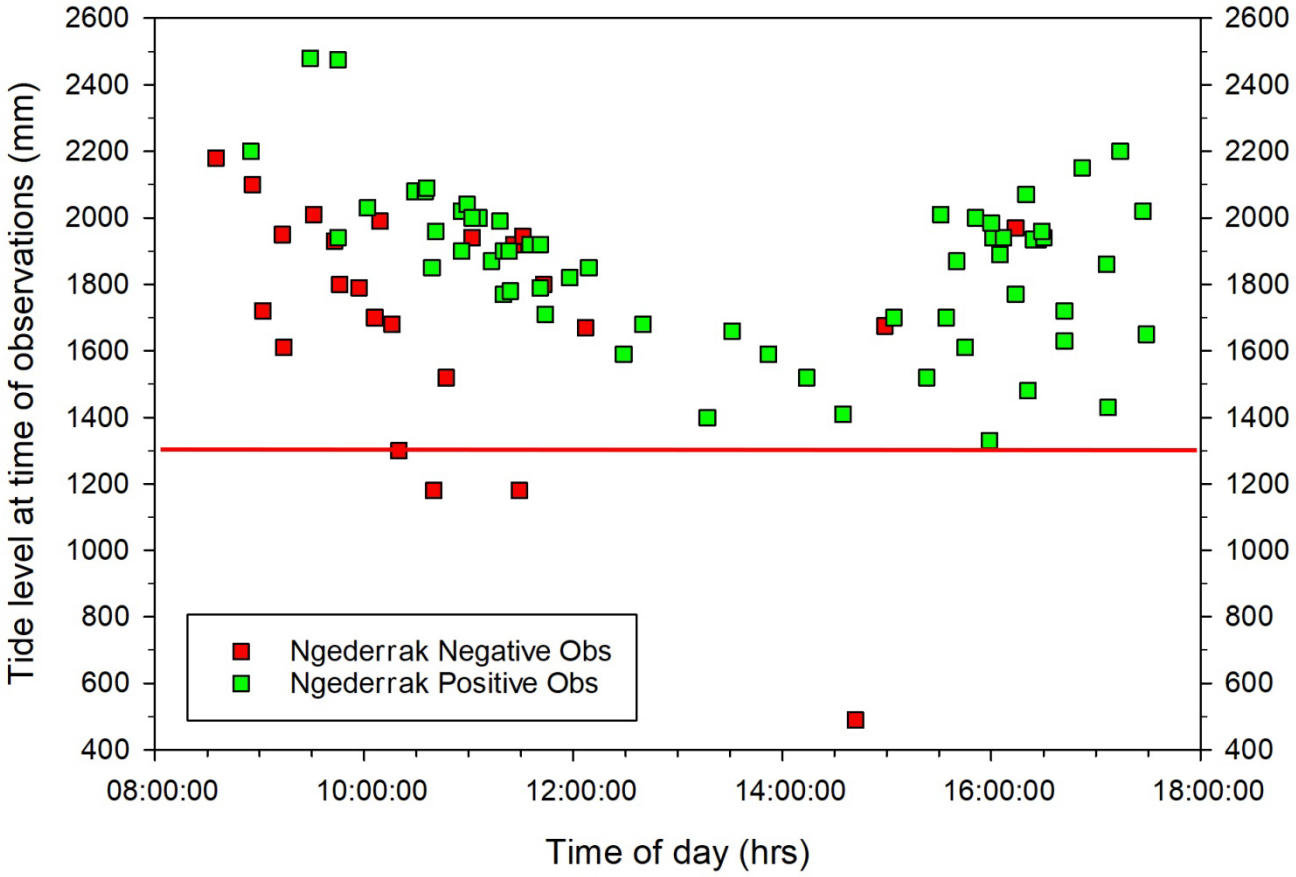

Figure 5. Relationship between tidal level and positive (dugong sighting)/negative (no dugong sighting) observations of dugong on Ngederrak over time of day. The red line at the 1300 mm datum level indicates the probable threshold for sufficient water depth on the flats for dugongs to access the area.

For Ngederrak Conservation Area, the relationships between water depth (tide level) and occurrence of dugongs in relation to time of day are shown in Figure 5. No positive observations of occurrence on Ngederrak were made at any tide level lower than 1300 mm on the Palau datum (Fig. 5). As can be seen, only a few flights were made over the Ngederrak area with tides below that level. These 4 flights were negative for dugong observations and we have some confidence that 1300 mm is a realistic value for minimum water depth for dugong occurrence on the flats.

Relative to time of day, it is apparent from Figure 5 that there are more negative observations (red squares) during Ngederrak flights in the morning than the afternoon. Figure 6 shows that the percentage of flights with positive observations of dugongs increased throughout the day, from only 30% during the 8:00-10:00 time window to 95% during the 16:00-18:00 time window. This observed pattern agrees with what former dugong hunters have said about dugongs, with them being more common during late afternoon than earlier in the morning in shallow areas.

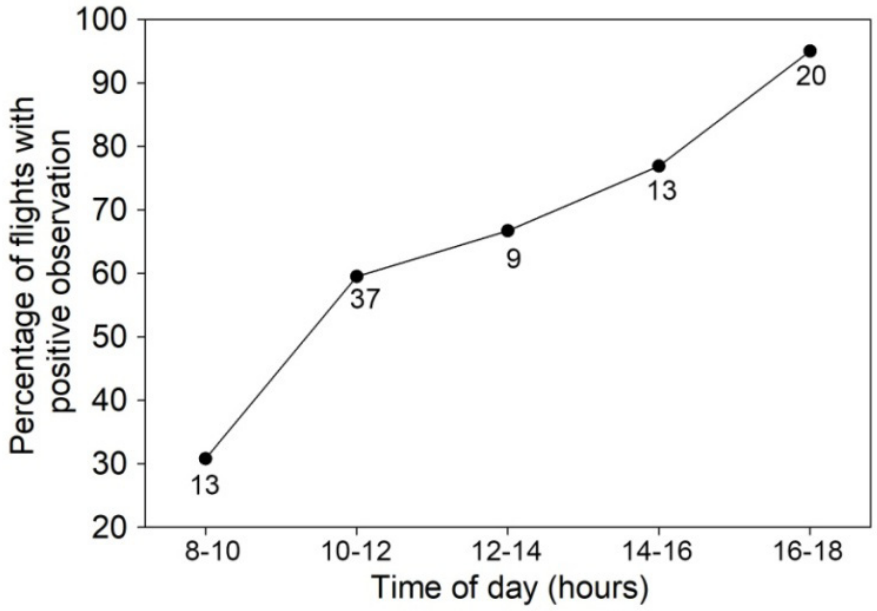

Figure 6. Percentage of drone flights over Ngederrak during which positive observations of dugong were made compared to time of day. Number of drone flights in each time period is shown below each data point.

For areas other than Ngederrak, where low tide levels did not exclude dugong presence, a different pattern was found (Fig. 7) with dugong present at all stages of the tide. This confirms the general pattern of dugong movement near the Ngederrak MPA described in Mandy Etpison's 2012 report (CRRF, 2012).

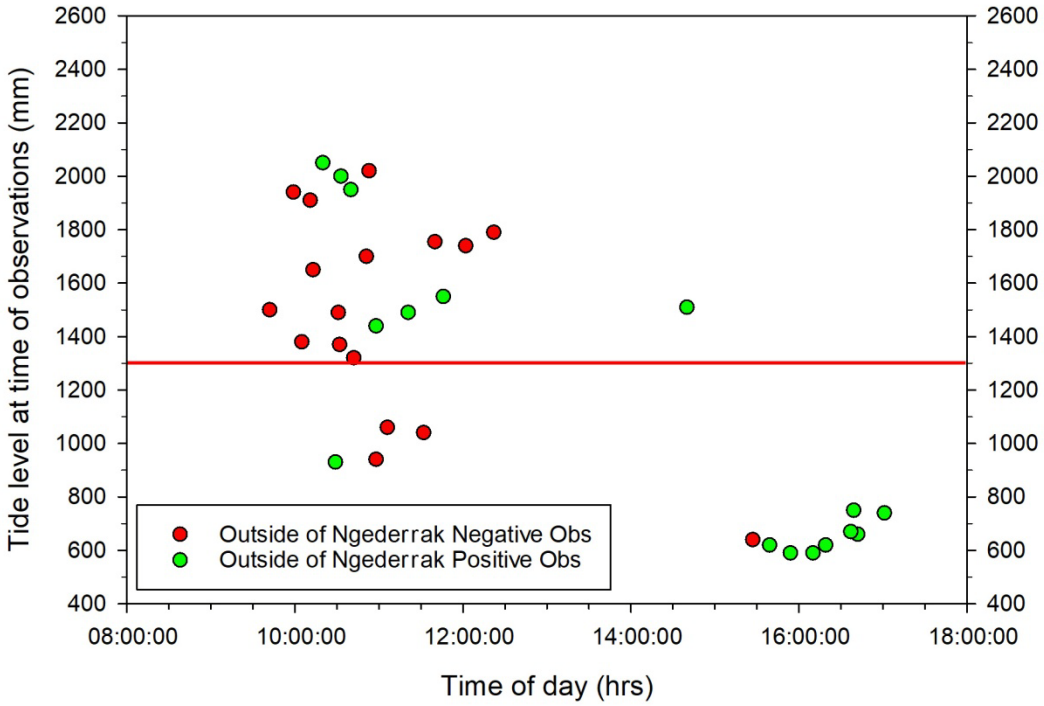

Figure 7. Relationship between tidal level and positive (dugong sighting)/negative (no dugong sighting) observations of dugong at areas outside of Ngederrak over time of day. For comparison with Figure 5, the red line at the 1300 mm datum level indicates the probable threshold for sufficient water depth on the Ngederrak flats.

The 2018-2019 period for this project had highly unusual tidal conditions, with exceptionally high mean sea level (MSL) during the early period when drone flights were made (starting March 2018) and extremely low MSL in late 2018-early 2019 (Figure 8). For most of 2019 MSL was near (within 100-150 mm) the long-term mean value (1540 mm) as indicated in Figure 8. We now have an excellent data base for the movement of dugong relative to tidal conditions and will build on this in the future. With gradually rising global sea levels (approximately 3 mm per year) this rise does not pose any threat to dugong populations. Instead rapid El Nino Southern Oscillation changes in MSL are the more important factor to consider when assessing whether climate change will have any effect on dugong habitat and behavior.

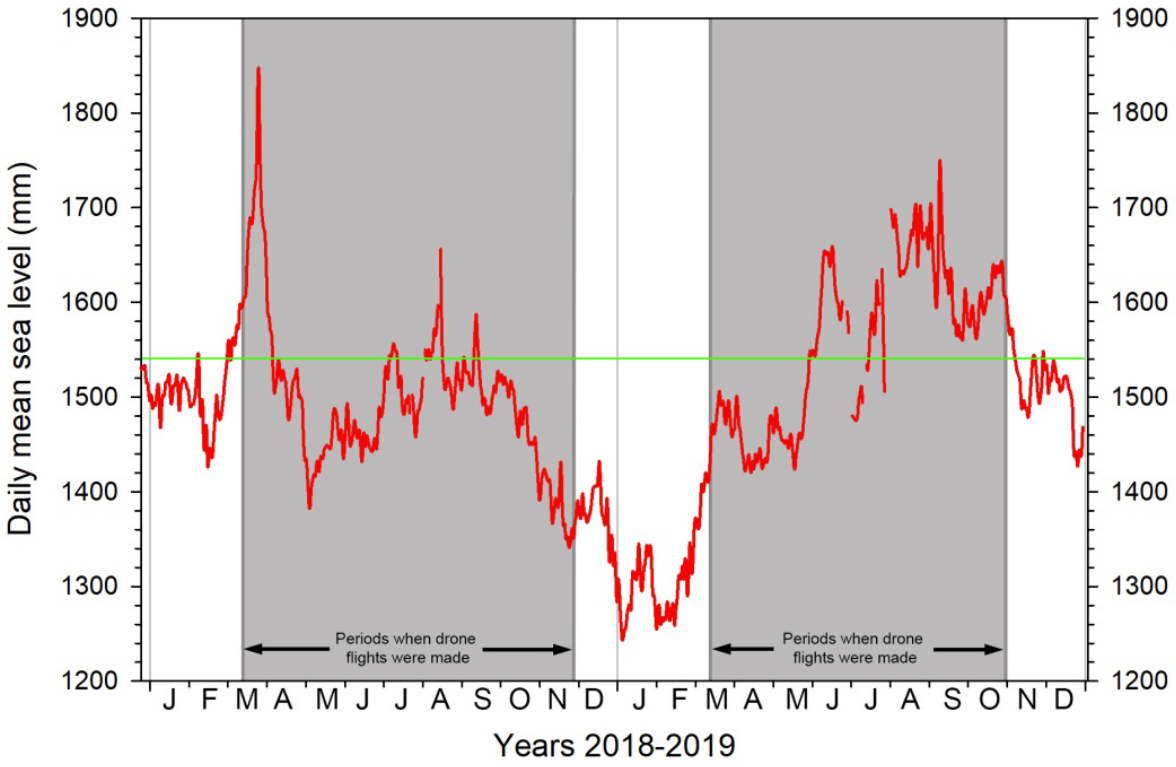

Figure 8. Daily mean sea level (red line) relative to the Palau datum during the period of project observations, 2018-2019. The green line indicates the long-term mean sea level for Palau (1969-2019). Shaded gray area indicates months when drone flights were made.

Ngerchelong State - Preliminary Information on the dugong population:

While our work was taking place, Lightning Strike Productions was starting to do drone flights in the area north of Ngerchelong State, at the northern end of Babeldaob (see https://www.facebook.com/lspfilm/videos/374367483115681/ at 30 sec).
Reports indicate significant numbers of dugongs occur in that area, but detailed information, such as exact positions of dugong, time of flights and tide level are not available. However, given this documentation of dugong occurrence, the northern Babeldaob area is a location that needs considerably more detailed investigation as to the status of its dugong population.

Are autonomous cameras a useful tool for observing dugongs?

We deployed autonomous Go Pro camera systems for many days on the Ngederrak flats area to determine if such systems are a useful tool for examining dugong movements and behavior. Two types

of systems were used; the first which took a short video sequence at programmed intervals and the second taking still photos continuously at a 1 min interval. Both types of systems successfully captured footage/images of dugong and we consider that each has a particularly utility for this work.

The video sequence system is most useful for deployment in areas where the movements of dugong are predictable, and you are interested in capturing behavior or other attributes, such as remora (tabi) "load". The second type is more suited to situations were occurrence is unpredictable, hence a longer, but regular sampling interval is needed. The one min interval proved to be too long between frames, as dugongs could swim by during the interval and not be captured as an image. A shorter interval of 10 seconds would work better, but reduces the length of deployments. The ideal system would be one in which the camera, either video or still, is triggered by passage of a large organism (dugong, shark, etc) to record for a period of time, then shut down waiting for another individual. This sort of thing is accomplished by acoustic tagging of individual organisms, but acoustic tagging is not practical or ethical for dugongs.

Mortality: Causes and the future?

Shortly after the project ended a single dugong death was reported. On Feb 5, 2020, the Koror State Rangers brought in a recently-killed dugong from near Dolphin's Pacific in Malakal Harbor. A necropsy was undertaken and it was discovered that a sting ray barb had penetrated the abdomen of the animal (Fig. 9). No other indications for cause of death were found. The necropsy was done by Dr Sayaka Suzuki, DVM (Koror State Government) and Dr Ryo Suzuki DVM and Elisabeth Howard (Dolphin's Pacific). Tissue samples and gut contents were collected by Lori Colin of CRRF. This is the 10th record of a dead dugong recorded by CRRF, 9 of them since 2010. It is the 2nd record of a dugong with an 8.5 cm sting ray barb in its abdomen. During the necropsy, Palauans indicated that it is not uncommon for a dugong to be killed by a stingray. The Feathertail stingray, *Pastinachus sephen,* is the most probable culprit species as they are common on Ngederrak in the seagrass beds. This phenomenon is known in other areas, such as Australia, Thailand, Okinawa etc.

Figure 9. A dead female dugong with an abdomen puncture made by a sting ray barb, the most probable cause of death (5 Feb, 2020).

No other dead dugongs were brought to our attention during our project period. Interestingly, most of our previous samples were mostly from assumed hunted animals during the previous dugong awareness campaigns. To our knowledge, no person has ever been arrested in Palau for dugong poaching.

Dugong behavior: Are dugong repelled or attracted by boats?

Dugong are hard to see from a boat when they resting on the water's surface, hence would seem likely to become injured from small boat traffic. However, there have been very few reports of dugong in Palau being struck by power boats, which is surprising given the large number of outboard boats which transit by the Ngederrak area and other dugong sites daily. The local view in Palau is that dugong dive when a boat approaches, which would tend to explain the lack of collisions. However, there were no actual observations of interactions between boats and dugong, hence we were interested in closely observing such behavior if possible.

During one drone flight over open water east of Ngederrak, we had the opportunity to carry out a controlled encounter between our mother vessel, a 12 m long catamaran with twin outboards, and a large dugong. The dugong was spotted on the surface by the drone in open water, between the sunken barrier reef and inner reefs complex, including Ngederrak, slowly swimming. Our boat was only a few 100 meters away and we decided over several minutes to slowly move towards the dugong, so determine, via the drone video, if and when it might react to the approaching boat. We slowly approached the dugong, with one person on our bow keeping a careful watch so we would not come close to contacting the dugong. As the boat approached within about 15-20 m the dugong, it sank from sight and by the time the boat had arrived at the location where the dugong had submerged, it was no longer present. It surfaced a few minutes later about 50 m distant and continued swimming slowly, seemingly unperturbed by the encounter with our boat. While anecdotal, this provided limited reassurance that dugong in Palau will flee from boats by simply submerging, not swimming on the surface.

Dugong behavior: Guarding behavior relative to sharks?

The aerial drone offers a remarkable opportunity of observe behavior of dugong and other species on the reef/seagrass flats impossible to achieve by other means. On one flight we observed for many minutes a dugong, separated from a family group, shadowing a shark (Fig. 10), remaining between the shark and the dugong group which can only be interpreted as behavior preventing the shark from approaching the larger group, which also had calves.

Figure 10. An adult dugong shadowing a shark on Ngederrak reef. Video footage indicated the dugong was preventing the shark from approaching the larger group of dugongs nearby.

Communication through visuals:

Many of the drone flights provided not only valuable scientific information on dugongs but also yielded spectacular visuals (video footage, stills, Figure 11), as shown in our previous progress reports. We are conscious that the unique clarity of water in the dugongs' habitat in Palau provides an unparalleled

backdrop to our footage not readily seen elsewhere in the world. Typically dugongs tend to be observed over sandy seagrass meadows that often lead to cloudy water. The footage and stills we obtained through this project were used in outreach and illustration materials and will be used to greater extent in future materials and publications.

Figure 11. Screen shots from video footage of dugongs outside Ngerderrak reef (above) and feeding in the Ngederrak sea grass bed (below) can provide amazing visuals for Palauans to encourage appreciation of the dugong's unique status and its need for protection.

Objective 2: Revive and increase awareness and appreciation of the environmental and cultural importance of the dugong among the Palauan public.

Outputs delivered under Objective 2:

The delivery of informative presentations on dugong biology, legends, threats, conservation science and their cultural value (Appendix I) to 12 schools (288 students in total; 150 females and 138 males) and to three conservation offices (22 officers; 9 females and 13 males) was a great success (Table 2, Fig. 12 & 13). Additionally, we presented to the public at two events (1) the Independence Day 2018 celebrations under the KB bridge, and (2) the Ocean Day event coordinated by the PNMS Office at the Friday night market at Ernguul Central Park in November, 2018. We reached ~120 people at the two events. The distribution of informational materials for the general public and the design and integration of educational activities targeting youth at local schools was also one of the highlights of this project. Posters, dugong stickers, bumper stickers and a banner (all on display in this report) were created by a young Palauan conservationist, Ms Miel Holm. Our focus on youth to foster and revive cultural pride and ecological awareness of the Palau dugong was rewarded with consistent and endearing enthusiasm from the students. Visitors to the night markets were equally intrigued and curious about the VR experience, which elicited much excitement and many questions. We hope that our engaging school activities promoted improved retention of learned materials and encouraged cross-disciplinary teaching using the dugong to integrate inter-related topics such as conservation science, life history biology, habitat ecology, geography, literature, and careers in science and technology. The video we used for the VR experience can be viewed on the CRRF website: https://coralreefpalau.org/projects/dugongs/.

Table 2: Summary of the presentations completed at local schools and conservation offices

	School Name	**Grade**	**Female**	**Male**
1	Aimeliik Elem.	4th & 5th	6	6
2	Meyuns Elem.	4th & 5th	18	15
3	SDA Elem.	5th only	22	15
4	Airai Elem.	4th & 5th	19	17
5	Melekeok Elem.	4th & 5th	16	11
6	Ibobang Elem.	2nd - 8th	8	9
7	PMA	9th & 10th	26	23
8	Ngardmau Elem.	1st - 8th	14	12
9	Ngaraard Elem.	4th & 5th	5	6
10	Kayangel Elem.	1st - 8th	4	4
11	Ngarchelong Elem.	4th & 5th	10	17
12	PHS Special Ed	9th-12th	2	3
			150	**138**
	Conservation office			
1	Ngiwal Conservation	Conservation office	5	3
2	Ngardmau Conservation	Conservation office	0	6
3	Ngaraard Conservation	Conservation office	4	4
			9	**13**
	Total of all people reached		**310**	

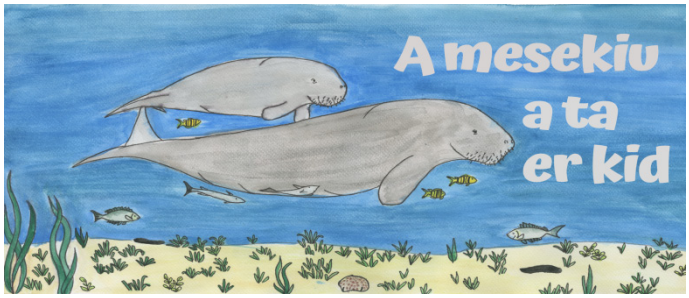

Figure 12: The school visits were a big success and one of the highlights of this project. Impressions from six of the twelve schools visited. Top left: Ngarchelong Elementary School; Top right: Aimeliik Elementary School; Middle left: Airai Elementary School; Middle right: Ibobang Elementary School; Bottom left: SDA Elementary School; Bottom right: Melekeok Elementary School.

Figure 13: Outreach to conservation offices: Ngiwal PAN State office (top row), Ngardmau OSCA Office (middle row), Ngaraard Conservation Officers (bottom row).

Objective 3: Inform and support management and conservation actions geared towards dugong conservation

Outputs delivered under Objective 3:

The overall messages to managers from this project are:

- The dugong population at the Ngederrak Conservation Area (NCA) is almost certainly stable, and most likely increasing slowly. Larger group sizes were observed during this study at high tide than in the 2010-12 dugong surveys.
- The Ngerderrak dugong population uses NCA in a relatively consistent way, with their feeding grounds limited mostly to one area, allowing for focused enforcement.
- Aerial drones, which are a readily available and deployable technology, have great utility in surveying dugongs. They also represent an affordable technology, compared to use of a helicopter, for an area of limited size.