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Article

Community-based Conservation of Leatherback Turtles in Solomon Islands: Local Responses to Global Pressures

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Abstract

The population of Leatherback Sea Turtles (*Dermochelys coriacea*) in the western Pacific has experienced dramatic declines over the past two decades. The full extent of these declines and the current status of the western Pacific sub-population remains unclear due to the remote nature of these nesting beaches. Zaira, on the southern coast of Vangunu Island in the Western Province of Solomon Islands is a previously undocumented nesting ground for Leatherback Sea Turtles. Whilst leatherbacks in this area have traditionally been harvested by the local communities, the Zaira community independently initiated a full closure over leatherbacks in 1999 as a response to reducing numbers. This study provides an overview of the scientific and traditional knowledge that the Zaira community has used to underpin their community-based management regime of Leatherback Sea Turtles. The community self-initiated the construction of a leatherback hatchery that was able to replicate the ideal nesting temperature for balanced sex ratios. Furthermore, the community developed a nest monitoring and satellite telemetry programme to provide a regional context to their conservation efforts. This community-led approach highlights the important role local communities can play in the conservation of this iconic species.

Keywords: Leatherback Sea Turtle, community, conservation, Solomon Islands, satellite telemetry, customary tenure, *Dermochelys coriacea*

INTRODUCTION

Leatherback Sea Turtles (*Dermochelys coriacea*) are a truly global species and are the most widely distributed sea turtle with foraging habitats ranging from Scotland to Chile (Wallace et al. 2013). Despite their widespread global distribution, leatherbacks are restricted to relatively few nesting beaches as successful egg hatching requires very specific conditions (Chan and Liew 1995). Due to predation by both feral and wild animals and increased human activities such as direct harvesting of turtles and unintentional fisheries bycatch of turtles, nesting rates of leatherbacks have declined significantly across the globe in recent decades. However, there are seven distinct sub-populations that are experiencing differing trajectories. Whilst the species is considered Vulnerable at the global level, the Atlantic population is projected to increase while the eastern Pacific population is now considered virtually extinct (Spotila 2000). The western Pacific population has declined over 80% over the past several decades (Tapilatu et al. 2013) and is considered Critically Endangered, with 2,700-4,500 nesting females remaining (Dutton et al. 2007; Wallace et al. 2013). The western Pacific leatherback population primarily nests in Papua, Papua New Guinea (PNG), and Solomon Islands. Of these areas, the

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nesting beaches in Papua represent over 75% of the total number recorded (Dutton et al. 2007).

Conservation of this iconic species is complicated by its global distribution and various interactions with human activities, as well as vulnerability to predation from pigs, dogs, monitor lizards, and humans during nesting (Limpus 1997). In addition, this species' nesting sites are typically confined to black lava sand (and in some cases white coralline) beaches, often located in the tropical Pacific region, representing a limited geography for successful nesting (Tapilatu et al. 2013). In some cases in Melanesia and Indonesia, local communities harvest leatherbacks and their eggs as a traditional food source, often associated with seasonal feasting or ceremonies (Hirth et al. 1993; Suarez and Starbird 1995; Benson et al. 2015).

In Solomon Islands, leatherbacks have been documented nesting on eight beaches, with highest densities of up to 100 nests per season on Tetepare, Rendova, Litogohira, and Sasakolo (Pita 2005; Dutton et al. 2007). Given the remoteness and lack of systematic leatherback turtle surveys, numerous undocumented nesting beaches that support low numbers of nesting leatherback turtles are also likely to exist in Solomon Islands. One such area is the south-western coast of Vanugnu Island. The area is comprised of a series of black volcanic sand beaches, with adjacent deep (>1,000 m) waters, that have historically been used by leatherbacks for nesting (McKeown 1977). Anecdotal evidence from the Zaira community on Vangunu indicates that up until the 1980s up to 50 leatherback nests were laid annually on beaches adjacent to Zaira, which was followed by marked declines from the 1990s onwards (N. Jino pers. obs.).

The distribution of Leatherback Sea Turtles foraging grounds and nesting beaches across remote areas of Melanesia intersect numerous customary land and sea tenure systems. Such intersections can complicate top-down management efforts for conservation of the population as customary owners often retain the right to harvest and consume turtles within their traditional fishing grounds. Where local communities have tenure over nesting beaches, co-management or community-based conservation approaches have proven useful for turtle conservation (Kennett et al. 2004; Campbell et al. 2009). In some cases, co-management approaches can be paired with incentive packages (Gjertsen and Niesten 2010) or tourism opportunities and/or conservation funding (Meletis and Harrison 2010; Pegas and Stronza 2010). Such inclusions can help to increase local acceptance and motivation of community members by providing associated livelihoods, revenues or other benefits that encourage respect of and adherence to conservation regulations and required or suggested practices. However, concerns have been raised that tourism and other incentive packages can lead to conservation efforts motivated primarily by economic and/or socio-cultural dynamics and benefits, mostly occurring at the individual level (Pegas et al. 2013). Critics note that an over-emphasis on economic aspects, while neglecting other considerations, can prove detrimental to the long-term sustainability of conservation efforts, by focussing on individual short-term gain rather than longer-term goals and benefits on a greater scale. Leaving too much to individual participation and/or economic incentives may leave elements of conservation interventions or related activities overly vulnerable to changing market forces (Campbell et al. 2007).

In addition to pressures from local leatherback harvesting, areas in the tropical western Pacific represent a global sea-level rise hotspot (Becker et al. 2012), which represents particular threats for sea turtles and their habitats. For example, sea turtle nests located in the high intertidal zone are increasingly inundated by rising sea level, leading to reduced hatching success (Poloczanska et al. 2009). The highly vegetated supratidal region often acts as a hard barrier to nesting since laying females are unable to dig through the tree roots in this zone. This pairing of threats to both mature female individuals as well as hatching success are both at work in the remote volcanic islands of the Solomon Islands (MacKay 2005).

Against this background, the local community in Zaira village on the island of Vangunu in the Western Province noticed a decreasing number of adults arriving at historic nesting beaches in the 1990s, and subsequently initiated a full closure over leatherbacks in 1999. Despite these management efforts, no successful nesting events (no hatchlings recorded) were observed from 1999 to 2010, despite several nests being laid each year (N. Jino pers. obs.). In response to this, the local community initiated a hatchery programme in 2011, to increase the hatching success of recently laid eggs. This paper aims to describe the innovative community-based management approaches used in Zaira and evaluate the outcomes of the hatchery programme. This approach may provide guidance for other communities within the region to approach conservation of Leatherback Sea Turtles.

METHODS

Site description

As in some other communities in the Pacific (Rudrud 2010), leatherback turtles (both meat and eggs) have been a traditional food item for the Vangunu people for centuries (Hviding 1996). Zaira village (population 150) on Vangunu in the Western Province of Solomon Islands has a rich oral history of interactions with Leatherback Sea Turtles. On a mountain above Zaira village, a stone curved in the shape of a leatherback turtle, known as *Karutolu*, was traditionally used to by the chiefs to determine when leatherbacks were likely to come ashore. When the stone was facing towards the ocean, it was supposed to indicate there would be a turtle coming ashore that could be harvested. Tribal chiefs would dictate how many leatherbacks should be taken, and when the turtles could be captured and killed. Leatherback meat would typically be cooked in a stone earthen oven and shared with the community during specific feasts. This customary use only resulted in limited harvests (1-5 turtles annually) (N. Jino pers. obs.). However, anecdotal evidence (N. Jino pers. obs.) suggests that harvest rates intensified during 1970's and 1980's to 10-20 turtles per year. The drivers of this harvest intensification are not clear. Due to local observations of declining leatherback presence in the area during the 1990s, the Zaira community implemented a total moratorium on leatherback harvests from 1999 onwards, independently from any external influence or assistance. This community-based management effort was/is championed by the tribal chief of Zaira, who commands respect from the broader community (Jupiter et al. 2017).

Despite this cessation of harvest, a recovery was not seen between 1999 and 2010 (N. Jino pers. obs.). Only a handful of nests were laid each year, with very few (less than 10 per year) live hatchlings observed over this period, compared to estimates of >50 nests each year historically (N. Jino pers. obs.). The last few decades have also resulted in substantial recession (>10 m) of nesting beaches due to coastal erosion (N. Jino pers. obs.), so increasing inundation of nests by seawater is one possible barrier to recovery. In response to the increasing inundation and the lack of a leatherback recovery, the local community designed and built a turtle hatchery in 2011 to provide a site to relocate eggs above high tide, in an attempt to increase clutch success.

Whilst the relocation concept was drawn from existing relocation programmes in Solomon Islands (e.g., Arnavon Islands Marine Conservation Area), the Zaira hatchery was designed locally with no external advice or assistance and was solely based on the detailed traditional ecological knowledge of nesting requirements the Zaira people possess. Community members hand-excavated a 25 sq. m area that is 1 m deep amongst coastal vegetation, and 5 m landward of the high tide line with an elevation of 1 m above the high tide line. All tree roots and soil were removed and replaced by the beach sand collected from areas where sea turtles typically nest. Vegetation overhanging the hatchery was pruned in order to increase incident sunlight to mimic sun exposure in nesting areas on adjacent beaches (N. Jino and H. Judge pers. obs.). A wire mesh fence 1 m high and extending 200 mm into the ground was constructed around the hatchery to prevent egg predation by dogs and pigs.

As a result of this pro-active management of leatherbacks, the Zaira community gained the attention of the regional conservation community in 2011, including the American Museum of Natural History. They also gained some limited support for equipment and monitoring training from The Solomon Islands Government, The University of Queensland (UQ) and a local non-governmental organisation (NGO), Solomon Islands Community Conservation Partnership (SICCP). These external partners were also able to facilitate connections between Zaira and other turtle conservation efforts in Solomon Islands and to regional monitoring initiatives. This external support helped to formalise the existing traditional management and initiate a monitoring programme undertaken using local rangers. The Zaira ranger programme is primarily focussed on the Leatherback Sea Turtle programme where a head ranger and six additional rangers from the Zaira and Oloana settlements undertake all the relevant duties on a voluntary basis.

Since June 2011, local rangers have conducted night-patrols on leatherback nesting beaches (Figure 1a) during two seasons based on traditional knowledge of nesting seasonality (May to July, and November to January). If rangers detect a nesting turtle, they allow the individual to complete nesting prior to Passive Integrated Transponder (PIT) tagging and collection of morphometric measurements to populate the Turtle Research and Monitoring Database System. Rangers dig up all the eggs from the nest (Figure 1b) and relocate them to the hatchery area, where they are reburied at a similar depth and orientation in the sediment. Each new nest within the hatchery is then marked with sticks and the sand surface monitored for signs of hatching activity. After nest emergence, an inventory is taken of live hatchlings and non-viable eggs/dead hatchlings (Figure 1c) and data entered into a central database (O. Revoh pers. comm.).

Sediment incubation temperature is a critical determinant of hatching performance with a narrow band between 27 ^{o}C and 32 ^{o}C critical to hatching success and swimming ability (Fisher et al. 2014). Sediment temperatures during incubation were measured in relocated nests by burying a temperature logger (HOBO Pendant® Temperature/Light 64K Data Logger, Onset Computer Corporation, Bourne, MA) adjacent to the egg matrix. Parallel sediment temperature logging was undertaken at the original beach nests, with logger depths matched to the nesting depth. Ambient air temperatures were monitored using a commercial weather station (HOBO U30-NRC Weather Station, Onset Computer Corporation, Bourne, MA) installed near the relocation area. Temperature logging intervals were 10 minutes for the duration of the incubation period from egg relocation until hatching.

On selected individuals (based on a decision by the head ranger), Argos satellite telemetry tags (Sirtrack F4) were attached to the carapace of three nesting females using methods described in Fossette et al. (2008) (Figure 1d). Telemetry data were downloaded on a weekly basis and filtered to exclude poor location quality (Argos location class A, B, 0). Through interactions between Zaira rangers and rangers from nearby Tetepare Island, satellite tagging was identified as a need to showcase the regional impact of their efforts. This demonstrates that, even with very limited support, highly advanced monitoring techniques can be undertaken if a community is willing. The University of Queensland supported the Zaira rangers to purchase the satellite tags. Outside of the nesting season, the local community traversed the beaches daily and reported no signs of tracks or nesting activity.

RESULTS

Turtle nesting/success data

From June 2011 to July 2014, 11 Leatherback Sea Turtles successfully nested on beaches between Zaira and Sangivi (Figure 1a). Nesting occurred in two distinct seasons from May-July and from November-January each year. Between June 2011 and July 2014, seven nests were recorded by Zaira rangers in January, five in June, three in July, four in November and four in December. A total of 23 nests were observed, with one turtle recorded nesting successfully six times and another recorded nesting five times. The other nine turtles were only observed nesting once or twice and it is likely that some nesting events were not recorded or the females nested on surrounding beaches not monitored by this study. The recorded nests had a mean of 94.6 eggs (smallest clutch: 66; largest clutch: 124), excluding yolkless eggs. Nesting females typically dug nests on the upper portion of beaches close to the vegetation line to a depth of 60-90 cm. The majority of nests had water present in the bottom of nest.

To date, 2175 eggs have been relocated from the 23 nests into the hatchery. The nests hatched with 66.8% of eggs (lowest success in one nest 27.8%; highest success in one nest 92.6%) successfully hatching after a mean incubation time of 67 days (quickest incubation time in one nest 60, slowest incubation time in one nest 74) (Figure 2).

RELOCATION SUCCESS

Nest temperature

Sediment incubation temperatures within the relocated nests had a mean of 29.6 °C and ranged between 27.2 °C and 32.2 °C (Figure 3). The mean temperature within the beach nest locations were more than 1.5 °C below the relocated nests and the lower range was below 27 °C. The relocation site was able to maintain mean temperatures of 2 °C above that of ambient air temperature (27.4 °C) over the duration of the monitoring period.

PIT Tagging

PIT tags were attached to rear flippers of eleven females over the 3-year monitoring period. While tagged individuals were observed multiple times during a single nesting season, no individuals were re-observed in subsequent nesting seasons. In addition, no tagged individuals were observed with pre-existing tags.

Post-nesting migration

The importance of the Zaira conservation efforts in the Western Pacific is highlighted by the satellite tracks observed for all three tagged individuals (Figure 4). Princess Zaira was the first individual tagged on June 16, 2014, during her first recorded nesting on Zaira. After her fifth nesting, she then began a westward migration tracking to the south of Tetepare, Simbo and Mono Islands before travelling close to land on Bougainville Island adjacent to a known leatherback nesting beach at Empress Augusta bay. She then continued westward

Figure 1
(a) Example of black sand nesting beach near Zaira Village, Vangunu Island, Solomon Islands. (b) Eggs being relocated post-nesting. (c) Head ranger taking an inventory of hatchlings and non-viable eggs post-emergence. (d) Zaira rangers attaching Argos tracker

until the signal was lost after travelling close to shore (within 2 km) on New Ireland, PNG on August 21, 2014. Princess Zaira travelled approximately 766 km (straight line distance) over 12 days with a mean speed of 2.5 km/hr during her north westward migration.

A second Argos satellite tag was attached to the carapace of a nesting female (named Princess Malia) at Marungu beach on November 15, 2015. This individual nested a further three times and then embarked on a 700 km westward track towards the Louisiade Archipelago in PNG. She then tracked eastward before the signal was lost (after 186 days) in the vicinity of Tagula Island (Figure 4). Princess Malia travelled approximately 1,600 km (straight line) in total with a mean speed of 1.4 km/hr during swimming periods.

A third Argos satellite tag was attached to the carapace of a nesting female (named Qua Zaira) at Marungu beach on January 7, 2016. This individual nested once more before embarking on a southward track towards New Caledonia and to the north island of New Zealand. She then tracked northward to Fiji before returning towards the north island of New Zealand before the track was lost. Qua Zaira travelled approximately 6,600 km over 176 days, with a mean speed of 1.6 km/hr during her migration.

Inter-nesting migration

Princess Zaira nested five times in total and spent nine to 11 days at sea between nestings. During three of these inter-nesting periods, Princess Zaira remained within a 30 km radius of open ocean to the south of Vangunu Island. Interestingly, she spent several days within 300 m of the active submarine volcanic seamount, Kavachi, which rises from a depth of 1800 m to 30 m below the surface. During the final inter-nesting period, she travelled to nearby Russell Islands, 125 km to the east (Figure 5).

DISCUSSION

The Zaira community have demonstrated that local actions can enhance Leatherback Sea Turtle hatching success and restricted harvesting of adults can have widespread impacts, with nesting females from Zaira observed to forage in regions over 3,000 km away in Fiji. The Western Pacific Leatherback Sea Turtle population has declined dramatically due to predation, harvesting, and fisheries by-catch (Kaplan 2005; Tapilatu 2013; Roe et al. 2014). In response to this long-term decline in the leatherback population, the Zaira community initiated a harvest ban in 1999. The key to the success of the harvest ban was primarily due to the intact nature of the community social structure, which has a well-respected tribal chief championing the conservation efforts (Jupiter et al. 2017).

The success of leatherback nesting may also be impacted by the accelerated sea level rise in the study region (Fuentes et al. 2010; Patino-Martinez et al. 2014; Albert et al. 2016). The resultant coastal erosion has greatly reduced accessibility to traditional nest sites through steepening the backshore and laying increasingly occurs near the swash zone. As water levels rise the risk of egg inundation during the incubation period increases especially as the egg laying season is timed to occur during the peak high tides in January and July.

In a context of conservation and environmental pressures, local people employed traditional knowledge of turtle nesting requirements as the foundation for a successful leatherback nest relocation programme that they initiated in 2011. Through centuries of oral history, the Zaira people have a detailed understanding of leatherback turtle nesting behaviour and seasonality that has evolved and adapted to more recent influences. Historically, the Zaira people have tended to use such knowledge in order to optimise egg and turtle harvesting. More recently (since 1999), the same traditional knowledge has informed conservation efforts. The local community designed and built the hatchery without any external support or advice. External partners provided resources and facilitated linkages, but are not building dependency on their presence and involvement, as they are not the main drivers or leaders of these efforts (Jupiter et al. 2014; Portman 2016). This self-initiated response to sea turtle-related conservation threats, such as

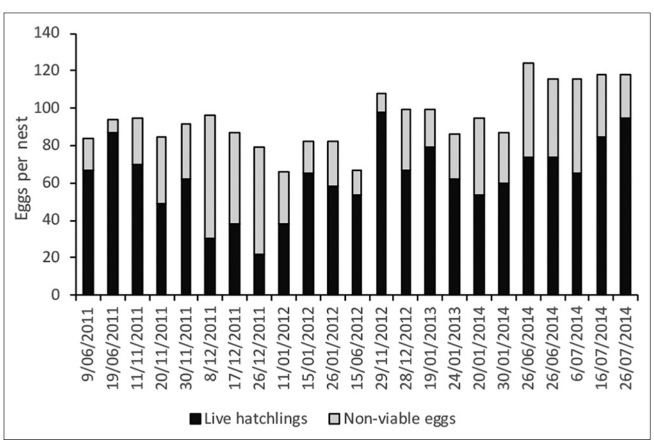

Figure 2
Hatching success of 23 relocated nests showing relative numbers of live hatchlings and non-viable eggs between June 9, 2011 and July 26, 2014

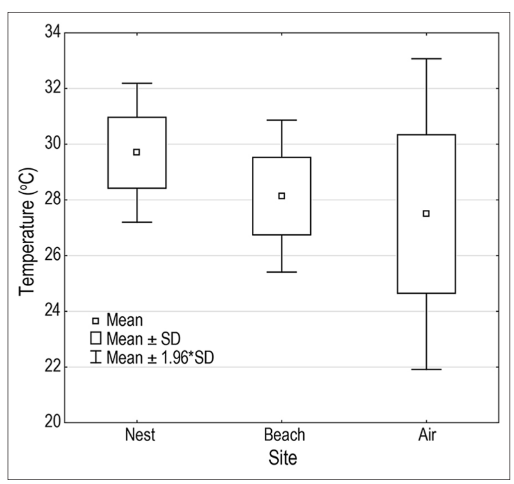

Figure 3
Sediment temperature of relocated nests and beach nests relative to ambient air temperature

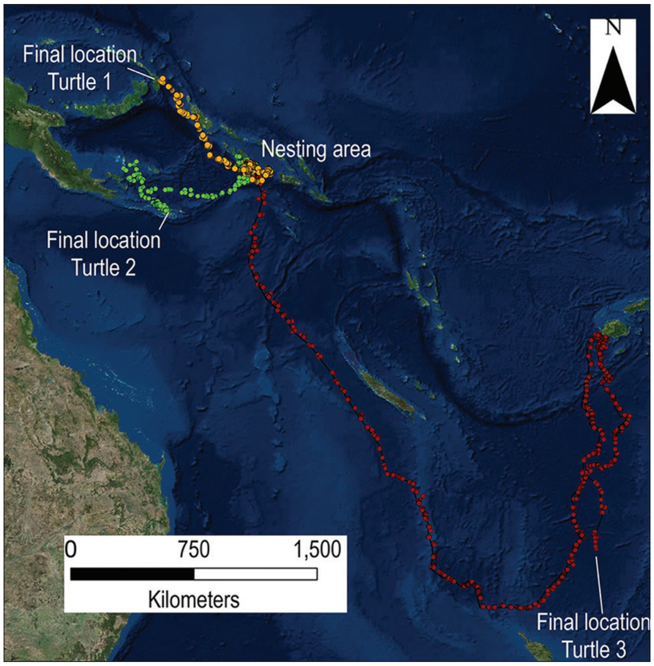

Figure 4
Satellite Argos tracks of three leatherback turtles tagged by the Zaira conservation rangers (orange—Princess Zaira, green—Princess Malia and red—Qua Zaira)

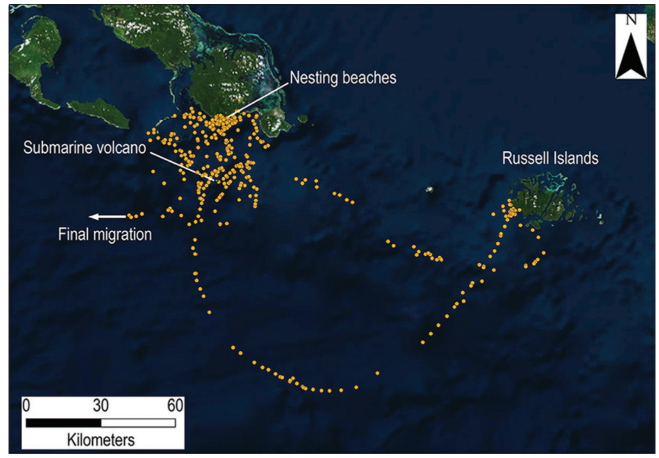

Figure 5
Satellite Argos tracks of inter-nesting foraging by Princess Zaira, showing the high density of activity within 30 km of nesting beaches as well as a single transit to the nearby Russell Islands

sea-level rise and observed harvesting pressures, demonstrate the adaptive capacity of communities in Solomon Islands to respond to environmental changes.

Addressing the nesting/hatching success through limiting predation and relocation of eggs into hatcheries is critical to slow the decline of this vulnerable species (Tapilatu 2013). Given the sensitivity of leatherback sea-turtle nests to temperature (Santidrián Tomillo et al. 2014), it is remarkable that the Zaira community was able to design and construct a hatchery drawing solely on their traditional knowledge of leatherback nesting habits. Excavation and placement of specific sand types into the hatchery, clearing of overhanging branches for sunlight and burying of eggs at correct depth enabled the re-creation of conditions desirable for nesting success. Mean temperature within the relocated nests was 29.6 °C, close to the sex ratio tipping point of 29.5 °C (Chan and Liew 1995). Although there may be some advantages to increasing the female-to-male ratios in endangered species populations, Tomillo et al. (2014) note that above a sand temperature of 30 °C, the emergence success of nests also decreases. Therefore 29.5-30 °C appears to be the optimal temperature for Leatherback Sea Turtle nests. Long periods of rainfall may also influence nesting success and sex ratios (Houghton et al. 2007). Park rangers also suggested that rain (periods of heavy rainfall) could have affected the emergence success rates of some relocated nests in Zaira.

Although the Zaira community possess a rich body of traditional ecological knowledge of leatherback nesting behaviour and seasonality, they have no knowledge of where leatherbacks forage and migrate to between nesting events (N. Jino pers. obs.). The limited number of individuals returning to Zaira for nesting in subsequent years indicates they may be vulnerable to harvesting or bycatch whilst nesting or foraging in unprotected areas. Previous satellite tagging of Leatherback Sea Turtles in Solomon Islands (Isabel and Malaita Province) has indicated inter-nesting movements within 200-400 km of nesting beaches (Benson et al. 2011). Migration tracks of the three turtles from Zaira indicate the diversity of inter-nesting and post-nesting foraging grounds. All three turtles tracked spent a proportion of their inter-nesting time in close proximity to the Kavachi submarine volcano. Hydrothermal vents, such as Kavachi, can significantly stimulate the productivity of surrounding waters, elevating zooplankton and jellyfish biomass (Burd and Thomson 2000), a key part of the leatherback diet (Davenport 2017). Kavachi is a very shallow volcano, less than 30 m below the water surface (Phillips et al. 2016), and this would make the food items readily available to the visiting leatherbacks. In addition, it is a highly active volcano with eruptions occurring at sub-daily timescales, which would allow individual leatherbacks to easily navigate to the area.

Despite the success of hatching over 1,400 leatherbacks in three years, post-nesting migration tracks highlight the regional level at which management efforts are required. Post-nesting movements of Western Pacific Leatherback Sea Turtles are highly varied, with the turtles primarily utilising foraging grounds in California, Tasman Sea, Papua, Borneo, PNG, Solomon Islands, New Zealand, and the Central Pacific during the six to eight months between nesting events (Benson et al. 2011). The three turtles fitted with satellite trackers in Zaira, all displayed different routes within the surrounding area, reflecting the geographic diversity of previous leatherback tracking studies. Princess Zaira travelled to the northwest, to PNG. Princess Malia moved to the southwest, to Milne Bay in eastern PNG. Qua Zaira travelled south to New Zealand before travelling to Fiji.

In addition to the direct positive outcomes for the Western pacific leatherback population of increasing hatching success from near zero to over 450 per year, the conservation efforts for leatherbacks in Zaira has evolved into a flagship community programme with multiple indirect benefits. The iconic nature of leatherbacks has gathered broad community support that has also led to a 4,000 ha ridge to reef conservation area adjacent to the nesting beaches (Jupiter et al. 2017). This has been fostered through a sense of pride within the Zaira community of their conservation programme, based on the fact the limited research and monitoring that has occurred has been designed and implemented by the community (McCarter in press). Whilst conservation efforts have been locally driven, the external partners (University, Government, and NGO) have provided a sense of formalisation that has helped to motivate the work by supporting and facilitating it.

Whilst the community-driven approach to leatherback turtle conservation and management appears to be effective in Zaira given it has been ongoing since 1999, it remains vulnerable to outside forces and changing community motivations (Jupiter et al. 2017). Motivations for management of leatherbacks in Zaira appear to be driven by local identity, maintenance of land tenure, and genuine local concern about declines in leatherback populations in recent decades. In contrast with many other community-based sea turtle conservation programmes, community participation in this project is not motivated by direct economic incentives or benefits, so is less vulnerable to changing market forces. The long-term security of this conservation effort could be improved by co-management (Berkes 2005) whereby the community-driven approach is balanced with formalised legal protection and enforcement through the national government such as that operating in the Torres Strait (Grayson et al. 2010). Given the large geographic range of leatherbacks nesting in Zaira, a regional transboundary approach to management of this critical population may indeed be required (Shillinger et al. 2008).

CONCLUSION

In conclusion, this study has described the successful implementation of a community-based leatherback conservation initiative, that began in 1999. The elevated hatchery area that the community constructed has been providing optimal nest incubation conditions for equal sex ratio in hatchlings as well as shelter from coastal erosion and inundation. This community driven nature of this programme is also facilitated by and augmented with technical support from external partners. This case highlights the potential for conservation success in areas with intact customary land tenure systems and traditional knowledge and use related to leatherbacks (Aswani et al. 2007). This is of particular importance for turtle conservation in the South Pacific region where much of the critical habitat is under customary land tenure and there is little governmental capacity to enforce a centralised conservation strategy. However, continued pressures from sea-level rise, by-catch, and predation of leatherbacks across the Western Pacific region continue to threaten the regional leatherback population, despite such conservation efforts. This greater context suggests that enhanced efforts to link community-based management with national government and transboundary efforts through co-management initiatives may extend the successes of such local initiatives and link them with greater networks and resources, for greater conservation impact.

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