Temporal and geographic distribution of hawksbill turtle (*Eretmochelys imbricata*) nests in Fiji, South Pacific

Shritika S. Prakash[1], Malakai Tuiono[1], Sophie Clay[2], Pita Qarau[3], Colin Philip[4], Katy Miller[5], Semisi Meo[6], Laitia Tamata[7], Saras Sharma-Gounder[8] and Susanna Piovano[1*]

[1] School of Marine Studies, The University of the South Pacific, Laucala Bay Road, Suva, Fiji

[2] Treasure Island Resort, P.O. Box 2210, Lautoka, Fiji

[3] Yadua Village, P.O. Box 90, Nabouwalu, Fiji

[4] Leleuvia Island Resort, P.O. Box 2540, Government Buildings, Suva, Fiji

[5] Vatuvara Foundation, P.O. BOX 588, Suva, Fiji

[6] Conservation International, P.O. Box 2089, Government Buildings, Suva, Fiji

[7] WWF-Pacific, 4 Ma'afu Street, Suva, Fiji

[8] Ministry of Fisheries, P.O. Box 13026, Suva, Fiji

*Corresponding author: Susanna Piovano,
email: susanna.piovano@usp.ac.fj

Introduction

The Critically Endangered hawksbill turtle (*Eretmochelys imbricata*) has a circumglobal distribution with nesting activities that have been recorded in 70 countries across the tropical and temperate regions (Witzell 1983; Mortimer & Donnelly 2008). One of the largest hawksbill nesting rookeries is in Barbados in the Caribbean, where there is an estimated total population of 1,250 nesting females (Meylan & Donnelly 1999; Beggs et al. 2007). Within the Pacific, about 220-580 hawksbill females nest annually in northern Australia (Hoenner et al. 2016; Bell et al. 2020). Fiji hosts nesting activities from two species of sea turtles: hawksbill, locally known as 'vonu taku', and green turtle (*Chelonia mydas*), locally known as 'vonu dina' (Guinea 1993; Bell 2013; Piovano 2018; Piovano et al. 2019). In the past, data collection on hawksbill nesting activity was conducted sporadically in time and opportunistically in space, mainly due to a lack of resources and limited scientific capacity. In addition, the results of these efforts often were not made public. As a consequence, only three pieces of grey literature are available on nesting hawksbills in Fiji. The first is a report that describes the effort and provides the findings of a sea turtle survey performed in 1979-1980 where, most prominently, the author was able to identify or confirm a total of 10 hawksbill nesting sites (Guinea 1993). The second is a series of slides used to present findings on 'critical habitats for sea turtles in Fiji' at a local conference (Laveti et al. 2011), based on information obtained from interviews, ground surveys and literature review, from which the authors highlighted a widespread distribution of hawksbill nesting sites throughout Fiji. The last one is a short report stating that an estimated 150-200 nesting events occurred in Fiji in the year 2000 (Batibasaga et al. 2006), but no methodology is described.

In Fiji, sea turtle populations are under pressure due to loss of habitats, natural predation, illegal harvesting of eggs and of nesting females, and climate change (Guinea 1993; Batibasaga 2002; Laveti & MacKay 2009; Laveti et al. 2011). Past anecdotal reports of decreased nest numbers have contributed evidence to support the declaration of a full protection status in 1995, when a series of moratorium and fisheries regulations made it illegal to 'harvest, sell, possess and transport sea turtles, their eggs or any part or product'. The last moratorium ended on 31 December 2018 and, since then, sea turtle species are protected under Regulation 5 of the Offshore Fisheries Management Regulations 2014. At this point in time, the lack of baseline data makes it impossible to judge if the measures taken were effective towards hawksbill population recovery.

The present study aims at addressing this information gap and provides a quantitative baseline for future comparison of hawksbill nests abundance in Fiji. For this reason, the University of the South Pacific Sea Turtle Team, with the assistance of international and local partners, has been collecting data on hawksbill nesting activities since 2014 (Piovano 2018). In this paper, we present nesting data collected from five consecutive nesting seasons: 2014/2015 to 2018/2019.

Method

Sites identification

The expected low density of nests, together with the geography of the Fijian archipelago (12°S to 20°S and 175°E to 177°W), where a coastline of 6,123 km (estimated from Fiji Ministry of Lands and Mineral Resources, Department of Lands, 1:50000 scale GIS data of Fiji coastline) is spread among more than 300 mostly uninhabited islands and 500 islets, make beach surveys difficult, time consuming and expensive. To overcome these issues and to maximize results, we chose to conduct site inspections upon receiving a notification of a possible nesting event (either tracks or presence of hatchlings) from our network of project collaborators.

Effort

Site inspections were carried out all year round from 2014/2015 to 2018/2019 upon receiving notification from the project collaborators or from the public. Site inspections were usually performed by SSP and MT during daylight, although on a few occasions, an inspection was carried out by the project collaborators alone, and night patrolling of the beach to target a returning nesting female was performed. For the latter, data collected were species and minimum curved carapace length (CCL), measured by using a flexible measuring tape. In addition, nesters were marked by applying a titanium flipper tag to the trailing edge of one front flipper while they were on their way back towards the ocean, after nesting. Upon confirmation of a nest ascertained during site inspection, geographic coordinates were recorded and, whenever possible, the date of discovery of the nest and/or oviposition were noted.

Mapping

The distribution of nests recorded during the five consecutive nesting seasons was mapped using ArcGIS® software (ESRI 2011).

Results

Nesting sites

We identified or confirmed 147 hawksbill nests across 27 active nesting sites (Fig. 1) during the 2014/2015 to 2018/2019 nesting seasons. Nesting sites identified in this study were located in all the four administrative divisions (western: 8 sites, northern: 7 sites, eastern: 6 sites, and central: 6 sites). Nests were recorded in all the nesting seasons and in all the divisions (Fig. 2). Overall, the highest number of nests (n = 99) was recorded in the northern division, followed by western (n = 33), eastern (n = 9), and central (n = 6) division. Five out of 27 sites recorded a total of more than 10 nests (Fig. 1), while two sets of sites recorded the highest total: Yadua and Yadua Taba Islands, which together hosted 35% of the total number of nests recorded, and Katawaqa and Nukuvadra Islands, which had 29% of the total number of nests (Table 1).

Biometric data of nesting females and hatchlings

Four nesting females were encountered, measured and tagged at three sites: Yadua, Katawaqa and Bounty Islands. Their mean CCL was 81.5cm (SD = ±3.7cm, Table 2). When possible, we also measured the size of the hatchlings corresponding to each known individual female, between 0-17 days post-emergence. Conservation projects at Bounty Island ran a captive programme where wild hatchlings hatched at Bounty Island were kept in tanks and released upon reaching a minimum size of 20cm CCL. On average, each female deposited 121 eggs/clutch (SD = ±35 eggs, n = 71 nests), and hatching success was 89% (SD = ±18%, n = 71 nests).

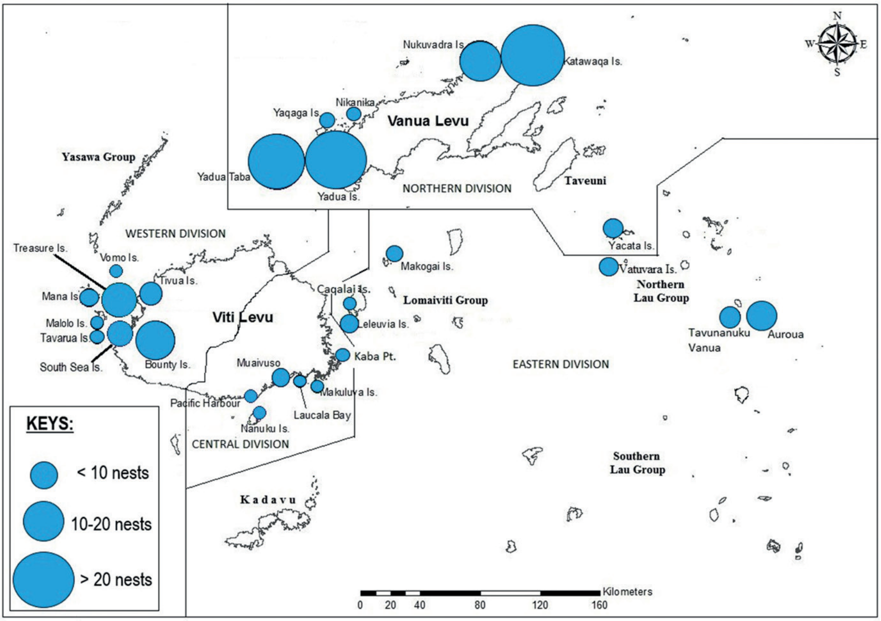

Fig. 1. Total nest distribution of the hawksbill turtle in Fiji during nesting seasons 2014/2015 through 2018/2019.

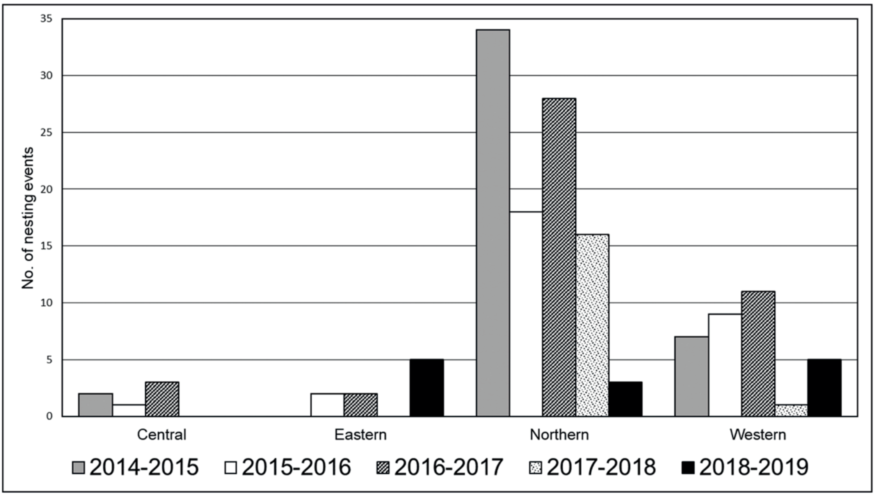

Fig. 2. Total number of hawksbill turtle nests in the four administrative divisions of Fiji, for each of the five nesting seasons.

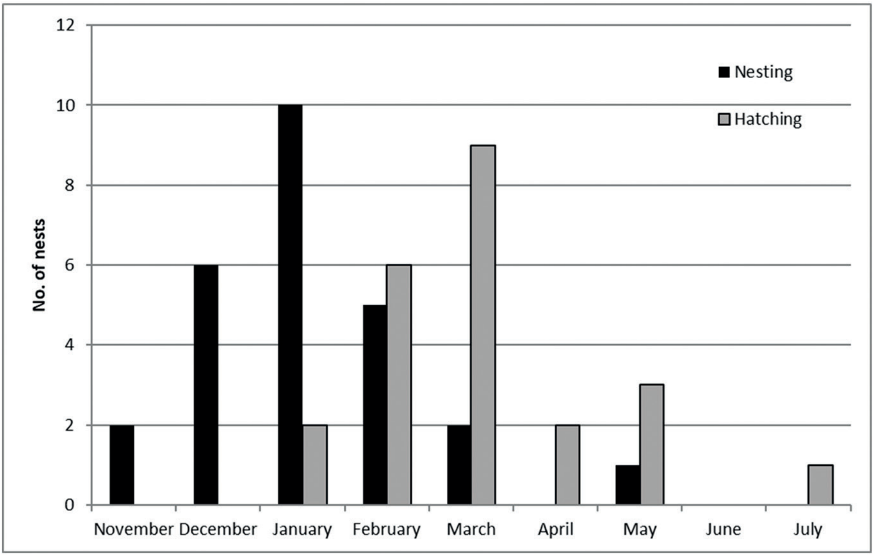

Fig. 3. Months of oviposition (nesting) and of hatching for the hawksbill turtle in Fiji.

Nesting and hatching period:

Nesting was recorded from November to May, with a peak in January (Fig. 3). The hatching period lasted from January to July, with a peak in March. The mean incubation period was 56 ± 5 SD days (range = 49-69 days).

Table 1. Geographic coordinates, name of site and number of nests recorded for Fiji, South Pacific, presented by administrative division. Is. = Island

Site	Latitude	Longitude	Nests	Nesting season	Source
Western Division					
Bounty Is.	17.6732°S	177.3055°E	3	2014/2015	This study
			2	2015/2016	This study
			4	2016/2017	This study
			1	2018/2019	This study
			1	2016/2017	This study
Malolo Is.	17.7523°S	177.1671°E	1	2014/2015	This study
Mana Is.	17.6733°S	177.1028°E	1	2014/2015	This study
			1	2016/2017	This study
Monuriki Is.	17.6095°S	177.0344°E	1	2013/2014	Vakacola, pers.comm.
South Sea Is.	17.6931°S	177.3129°E	1	2014/2015	This study
			3	2016/2017	This study
Tavarua Is.	17.8577°S	177.2018°E	1	2018/2019	This study
Tivua Is.	17.6141°S	177.3469°E	3	2016/2017	This study
Treasure Is.	17.6552°S	177.2669°E	7	2015/2016	This study
			1	2017/2018	This study
			3	2018/2019	This study
Vomo Is.	17.4927°S	177.2674°E	1	2014/2015	This study

Site	Latitude	Longitude	Nests	Nesting season	Source
Northern Division					
Druadrua Is.	16.1983°S	179.6128°E	5	2009/2010	Bell (2013)
Katawaqa Is.	16.1942°S	179.5598°E	70	2009/2010	Bell (2013)
			9	2014/2015	This study
			4	2015/2016	This study
			8	2016/2017	This study
			7	2017/2018	This study
Kia Is.	16.2301°S	179.0919°E	1	2005/2006	Bell (2013)
Koroinasolo	16.7456°S	178.5290°E	1	2009/2010	Bell (2013)
Laucala Is.	16.7589°S	179.6842°W	1	1979/1980	Guinea (1993)
Mali Is.	16.3427°S	179.3532°E	1	2009/2010	Bell (2013)
Namena Is.	17.1097°S	179.0990°E	1	1978/1979	Guinea (1993)
Nanukulailai Is.	16.7095°S	179.4492°W	5	1979/1980	Guinea (1993)
Nanukulevu Is.	16.7197°S	179.4537°W	14	1979/1980	Guinea (1993)
Nikanika Is.	16.5312°S	178.7297°E	1	2016/2017	This study
Nukuci Is.	16.4979°S	178.8461°E	2	2009/2010	Bell (2013)
Nukuvadra Is.	16.2217°S	179.5513°E	4	2014/2015	This study
			4	2015/2016	This study
			2	2016/2017	This study
			4	2017/2018	This study

Site	Latitude	Longitude	Nests	Nesting season	Source
Yacata Is.	17.2574°S	179.5247°W	2	2016/2017	This study
Yadua Is. & Yadua Taba Is.			26	2009/2010	Bell (2013)
Yadua Is.	16.8191°S	178.3003°E	12	2014/2015	This study
			4	2015/2016	This study
			6	2016/2017	This study
			4	2017/2018	This study
			1	2018/2019	This study
Yadua Taba Is.	16.8343°S	178.2781°E	8	2014/2015	This study
			6	2015/2016	This study
			9	2016/2017	This study
			1	2017/2018	This study
Yaqaga Is.	16.5883°S	178.5860°E	1	2014/2015	This study
Eastern Division					
Auroua Is.	17.7339°S	178.6548°W	3	2018/2019	This study
Caqalai Is.	17.7878°S	178.7306°E	1	2015/2016	This study
Leleuvia Is.	17.8077°S	178.7216°E	1	2015/2016	This study
			1	2016/2017	This study
Tavunanuku Vanua Is.	17.7616°S	178.8317°W	1	2018/2019	This study
Vatuvara Is.	17.4281°S	179.5284°W	2	2018/2019	This study

Site	Latitude	Longitude	Nests	Nesting season	Source
Central Division					
Kaba Point			1	2016/2017	This study
Laucala Bay			1	2014/2015	This study
Makuluva Is.	18.1879°S	178.5183°E	1	2015/2016	This study
Muaivuso			1	2014/2015	This study
			1	2016/2017	This study
Nanuku Is.	18.3409°S	178.1610°E	1	2016/2017	This study
Pacific Harbour			1	2016/2017	This study

Table 2. Data on four tagged nesting females and a subset of their hatchlings. Is. = Island; Captivity indicates the number of days the hatchlings born at Bounty Island spent in captivity at the same island before being measured.

Date of nesting	Site	Nester tag code	Nester CCL (cm)	Hatchlings CCL (cm) mean ± SD; n	Captivity (days)
26/01/2015	Yadua Is.	R54978	81	-	-
06/01/2015	Katawaqa Is.	R55001	77	4.2 ± 0.1; 10	0
05/12/2016	Bounty Is.	R50256	86	5.7 ± 0.5; 87	17
01/01/2017	Bounty Is.	R26753	82	4.3 ± 0.8; 15	8

Discussion

This study provides for the first time baseline data of the abundance and distribution of hawksbill nests in Fiji, as it is based on data and information validated in the field. We avoided overestimating the nest counts by excluding tracks without nests, and not recounting of old nests. However, this study should not be considered exhaustive, as some geographic areas could not be reached or incorporated into the project network, and some nests might have been washed out by high wave action during cyclones and tropical depressions before they were detected or verified. Thus, we acknowledge that, despite the effort, at the country level this count is an underestimate. Despite the limits of this study, we recorded an average 38 nests per season, suggesting that either Fiji hosts a small nesting population of hawksbill turtles, or that the population has not recovered yet.

This study identified or confirmed 27 nesting sites as currently active, the majority of which were not visited by nesting females every year. In terms of management, priority should be given to those nesting sites that host a relatively large number of nests and that consistently have nests during consecutive nesting seasons. In Fiji, priority for conservation and monitoring effort should be given to Yadua and Yadua Taba Islands, and Katawaqa and Nukuvadra Islands, in the northern division. These sites regularly hosted hawksbill nests almost every year and, altogether, accounted for 64% of the total number of nests reported in the five consecutive nesting seasons. These two sets of islands, of which only one is inhabited, should be monitored as index nesting sites and used to infer the status of the hawksbill population at large. Other active nesting sites are certainly present in the Fijian archipelago, and we suggest that further effort should be directed towards the outer islands; in particular, the Lau group, Kadavu, and the Yasawa group.

This study on temporal distribution of hawksbill nesting activity between 2014/2015 and 2018/2019 shows that nesting peaks in January, confirming previous suggestions of peaks in December-January (Hirth 1971; Guinea 1993), while the peak in hatching occurs about two months later, in March. Hawksbills, like all the other species of sea turtles, appear to prefer warmer months for nesting (Witzell 1983; Mortimer & Donnelly 2008). Although the summer in Fiji generally lasts from November to April, environmental conditions remain suitable for nesting and subsequent egg incubation in May. The atmospheric temperature determines the length of incubation period (Witzell 1983) which, in Fiji, was found to be 56 days on average. The identified period of December to March represents the core period (ca. 90% of nesting and ca. 75% of hatching events) when hawksbills should be given the highest protection with enforcement aimed at maximising nesting success. A longer period of enforcement, from November to July, will ensure full protection throughout the entire nesting season.

In general, hawksbill turtle nesters are smaller in comparison to other species of sea turtles (Heppell et al. 2002). Biometric data collected during this study suggest that the average CCL size (81.5cm) of mature hawksbills nesting in Fiji is similar to the size of hawksbill nesting in Nicaragua (80.1cm, in Witzell, 1983) and Australia (81.7cm in Loop et al. 1995), but smaller than those nesting in Brazil (97.4cm, in Marcovaldi et al. 2007). The smallest nesting female recorded in this study had a CCL of 77cm. From a management perspective, this size may serve as a proxy threshold to separate adults (≥77cm CCL) from juveniles (<77cm CCL) for monitoring the population dynamics of the hawksbill turtle in Fiji, although a larger sample size may lower the threshold.

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