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Final report on the green sea turtle egg-laying season of 2017-2018 *(Chelonia mydas)* on the atoll of Tetiaroa

- French Polynesia -

Convention N° 008232 /MCE/ENV of October 25th 2017: convention regarding the program of registration and protection of green sea turtle egg-laying sites (*Chelonia mydas*) on the atoll of Tetiaroa during the 2017-2018 season.

Final report on the green sea turtle egg-laying season of 2017-2018 *(Chelonia mydas)* on the atoll of Tetiaroa

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Table of content

Summary

The monitoring of green sea turtles on the atoll of Tetiaroa is a continuous research program, which started in 2007, under the management of the Te mana o te moana association. Within the convention's framework, monitoring carried out during the 2017-2018 egg-laying season, benefitted from the support of the Direction for the Environment and the Tetiaroa Society.

This season, the first ascension of female turtles is estimated to have occurred on July 12th 2017 and the last one on April 27th 2018; the egg-laying season lasted **289 days.** During this time period, **1 316 tracks were recorded, among which featured 626 nests,** most of which were found on the Tiaraunu, Horoatera and Onetahi *motu*, where more than 93 % of egg-laying events took place).

396 cases of adult female turtles observations were made at night, mainly on the beaches of the Tiaraunu and Onetahi *motu*, accounting for **96 individuals**. This season, the size of the entire atoll's sea turtle population has been estimated to **120 - 130 females**.

Thanks to in depth fieldwork, more than **80% of active nests were excavated**, which enabled the acquisition of reliable, valuable information regarding nest and emerging turtle characteristics. Active nests contained an average of **86 eggs** of which **79 hatched - 91% hatching success rate.** Results show that the depth of the nest had an influence on the hatching success rate, its peak being, when the nest measured between 50 and 75 cm.

During the excavation of the nests, **873 live, emerging turtles, which had gotten stuck,** were observed and saved. Out of the total amount of excavated nests, **more than 40 000 eggs** were found. It has been estimated that about **49 500 emerging turtles were born** this year on Tetiaroa.

This season was marking the testing of a new monitoring method on the Tiaraunu *motu*, using an infrared camera. Rare images were obtained, which enabled to bring to light **frequent rat predation** on emerging turtles, during the hatching phase.

Introduction

French Polynesia is composed of 118 islands (high volcanic islands and low coral islands), divided into five archipelagos (Society, Tuamotu, Gambier, Austral and Marquesas). Its total land area is 3 521 sq. km and it is part of an Exclusive Economic Zone (EEZ) of about 5 030 000 sq. km. (equivalent to the area of Europe). Five species of sea turtles can be found within this vast territory: the loggerhead sea turtle (*Caretta caretta*), the hawksbill sea turtle (*Eretmochelys imbricata*), the leatherback sea turtle (*Dermochelys coriacea*), the olive ridley sea turtle (*Lepidochelys olivacea)* and the green sea turtle (*Chelonia mydas*). The latter is, alongside the hawksbill sea turtle, the most common species found in French Polynesia (Petit & Gaspar, 2011). When it comes to sea turtle populations' biology and ecology in French Polynesia, our knowledge is fragmented. A major constraint is the vastness of the territory, which poses difficulties when it comes to the implementation of regular research programs.

To this day, only the green sea turtle is known to regularly lay eggs on the shores of French Polynesia. The major sites are located in the Society Islands, such as Tetiaroa (Petit et al., 2013), Scilly, Motu One and Mopelia (Balazs et al., 1995). Other less important sites have also been described, such as Tikehau (Tayalé, 2007), Maupiti and Fakarava (association Te Honu Tea).

Since 2007, the association Te mana o te moana conducts, with the valuable support of the atoll's owners, annual onshore monitoring on the egg-laying site of the Tetiaroa atoll, and since 2014, with the additional support of The Brando Hotel and the Tetiaroa Society. The high number of egg-laying events observed on the atoll in the last few years has contributed in making it one of French Polynesia's major sea turtle egg-laying sites. The purpose of monitoring is to catalogue the laying periods, gather data as complete as can be regarding the different criteria characterising the egg-laying events (tracks, females, nests, eggs, emerging turtles, immediate environment…), provide an index of the stock amounts and their evolution in time, and finally identify major sites for sea turtle egg-laying, to enable the establishment of conservation actions and adapt the relevant areas.

This season, in the framework of a convention, the Direction for the Environment has been supporting the monitoring of egg-laying events on the atoll, as it had previously done in 2007-2008. All other seasons have either been carried out by the association Te mana o te moana, using its own funds, or thanks to public and private support. Since 2015, the association has also been receiving support from The Brando Hotel, the Tetiaroa Society, Vilebrequin, Hinevara and the IFBD.

Material and Methods

I. Area of Studies

Tetiaroa is a private atoll located in French Polynesia. It is part of the Society Islands and belongs to the Brando family. Situated 53 sq. km north of Tahiti, it is the only atoll of the Winward Islands. It has a total surface of 6 sq. km, about 585 hectares of sand, and is divided into the following 12 *motu* (small islands): Onetahi, Honuea, Tiaraunu, Tauini, Auroa, Hiraanae, Horoatera, Aie, Reiono, Tahuna rahi, Tahuna iti and Rimatuu (Figure 1). Except in for Onetahi, the *motu* are not inhabited. Since July 1st 2014, the latter hosts the eco-resort The Brando. Presently, more than 300 people live there permanently, the majority of whom works for the hotel. The atoll also receives the daily visit of charter companies, which enable tourists to discover the *motu*'s beaches, such as Rimatuu and Tahuna iti.

During the 2017-2018 season, these 12 *motu* were prospected at least once by the Te mana o te moana association.

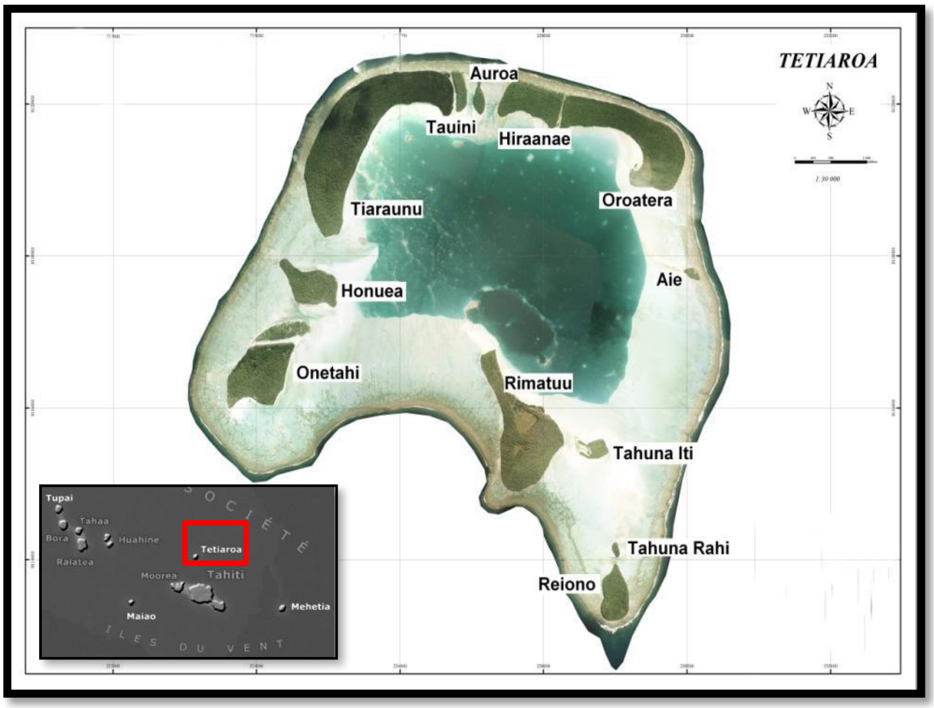


Figure 1 : Tetiaroa atoll

II. Field Team

During the 2017-2018 season, 20 people took turns in collecting data on the field, three of which remained permanently on-site. These people underwent a training program at the Moorea care centre, led by Dr. Cécile Gaspar (certified for sea turtles by Direction of Environment DIREN from French Polynseia Gouvernment), which focused on teaching them how to handle egg-laying turtles (baggage, measures, genetic sampling).

- **Touron Margaux**: marine biologist in charge of coordinating the project on-site, who was on Tetiaroa last season
- **Genet Quentin**: marine biologist
- **Leclerc Nicolas:** marine biologist, DIREN sea turtle DIREN Certified

Volunteers were able to assist the permanent team, for time periods varying from one week to a few months. They also followed a training program, either at the Moorea care centre or directly on Tetiaroa.

- **Balmy Coralie**: technician at the CESTMed care centre for sea turtles
- **Fioretti Antonin**: volunteer operating during the entire green sea turtle egg-laying season in 2016-2017 on Tetiaroa
- **Poutot Cécile:** volunteer at the Moorea turtle care centre since last year
- **Coch Edwige:** oceanography student at the Aix-Marseille University and intern for 3 months at the Moorea turtle care centre (July - September 2017)
- **De La Brosse Nicolas**: Captain of the Tara expedition
- **Bechetoile Brigitte**: volunteer at the Moorea turtle care centre since last year
- **Carpentier Alice**: marine biologist at the Moorea turtle care centre
- **Leroy Charline**: biology student at the French Polynesian University, who interned for one year at the Moorea turtle care centre
- **Tran Hanh**: started volunteering two months ago at the Moorea turtle care centre
- **Manceau Mai:** lagoon guide of the Moorea Island and volunteer dedicated to the monitoring of green sea turtle egg-laying events on Tetiaroa (2016-2017 season)
- **Rueda Remy**: emergentologist

Additionally, a few assistant volunteers joined the team, during the peak-time period of the egg-laying season. Due to the protection status of the species and their short amount of time spent on-site, these volunteers never handled the turtles.

- **Estall Tekura:** history student at the French Polynesian University
- **Busser Jules**: STAPS student at the Institut supérieur de l'enseignement privé de Polynésie (private university)
- **Hauata Grace:** geography student at the University of French Polynesia
- **Teikiotiu Teononui:** geography student at the University of French Polynesia
- **Tran Anne-Marie:** EIO Master 2 student at the University of French Polynesia and intern at the Moorea turtle care centre
- **Macary Fanny:** scientific data management engineer
- **Artaud Sebastien:** volunteer at the CESTMed sea turtle care centre

III. Field protocol

Based on the Polynesian environmental code, the green sea turtle species is classified under the B Category. Hence, since 2007, all administrative requests concerning the scientific monitoring of green sea turtles have been assigned to the Direction for the Environment.

This year, the main focus of the study was nocturnal prospection on 3 *motu*: mostly on Onetahi & Tiaraunu and less continuously on Horoatera. Regular monitoring has enabled the registration and identification of egg-laying females, thanks to the Capture-Mark-Recapture (CMR) method. The fact of ringing turtles monitored during the night time has enabled to acquire information regarding their egg-laying frequency, the time span before each new egg-laying event, the geographical distribution of nests created by the same turtle, but also the incubation time period of each nest.

Alongside nocturnal missions, daytime prospection was also carried out on a daily basis, dedicated to recording tracks and nests located on the various *motu*, in order to know the exact number of events, which occurred on the entire atoll this season.

1. Daytime prospection

Since the beginnings of monitoring on Tetiaroa in 2007, the method has remained the same. Daytime monitoring, taking place on the 12 *motu*, is executed in twos and aimed at locating turtle tracks (ascending/descending tracks, turned over sand, diggings...). In order to optimise the research, a first observer is in charge of monitoring the lower part of the beach, at the foreshore level, whilst a second observer prospects the higher part of the beach, located at the vegetation's edge.

The purpose of daytime monitoring is to identify the tracks left on the beach. All turtle species leave different kinds of tracks. This helps determine the species, which laid the eggs. On Tetiaroa, all the tracks discovered had been made by green sea turtles. The front flipper prints were deep and asymmetrical, which is typical of their moving patterns. The prints of the hawksbill sea turtles, commonly found in French Polynesia, are less deep and less asymmetrical.

When tracks or diggings are discovered, various characteristics are written down:

- ✓ **General characteristics of observation**: for each new track/digging, the observers' names, the date of the observation and the *motu*'s name are taken down.

- ✓ **Characteristics of the track and diggings:** upon the discovery of the track, the kind of ascension must be determined. The tracks are interpreted as follows: it can either be a simple track **(T)**, demonstrating that the turtle ascended and then descended without performing further actions; the track can be found alongside one or more diggings, which didn't lead to any egg-laying events, we call these "attempts" **(TN0)**; it can be found next to successful diggings, which led to egg-laying and in this case, either we can only suspect that there has been an egg-lay **(TN1)** or we are almost sure that it took place **(TN2)** or we are absolutely certain that it occurred **(TN3)**. The fact that eggs were laid can only be confirmed, if it has been observed or if the nest has been dug up and the eggshells counted after the hatching phase. (Figure 2).

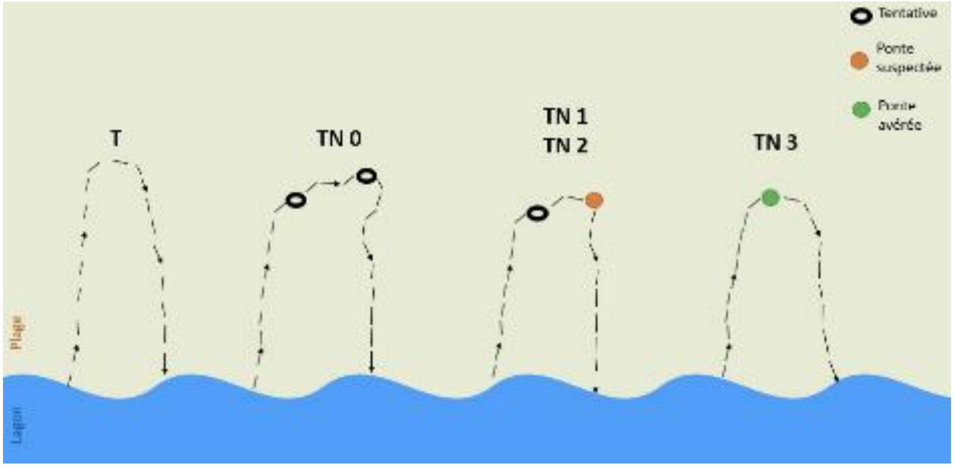


Figure 2: Diagram featuring the different kinds of recorded tracks

For each track, the number of attempts is counted and written down.

When a turtle track is spotted and the presence of a nest cannot be deduced, the GPS coordinates of the track's highest point are written down. If one or multiple diggings have been found, the last digging's GPS point is taken down. Hereafter, the objective will be to determine the last nest by figuring out the turtle's progression, based on the orientation of the prints left by its flippers.

Then, the track's degree of freshness will be assessed and put in the following categories: "fresh", "partially erased" and "erased". Based on the category, it will be possible to estimate the date of ascension. The degree of difficulty found in estimating the freshness of the tracks is correlated with the monitoring frequency of the site.

- ✓ **Environmental characteristics:** regardless of the type of ascension being considered, a few environmental parameters will be assessed, in order to collect information concerning their influence on the success of egg-laying and egg incubation.

  Thereby, qualitative measures are taken at the surface, such as the sand's grain size. If much of sand particles is inferior to 1 mm, the grain size is put into the "thin" category, and if the diameter of many these is superior to 2 mm, it will be put into the coarse category. In between these two numbers, the grain size was described as "medium".

  The light exposure of the nest or of the top of the track was also qualitatively assessed. The vegetative cover, from which resulted the light exposure, was divided into three categories, based on a 5m radius around the nest or from the track's top: "shady" (more than 50% of vegetative cover), "half-shady" (between 25 and 50% of vegetative cover) and "direct sunlight" (less than 25%).

The quality of the coastline facing the nest or of the last digging is also taken into account. This criterion is broken down into 3 categories: « sand », « coral slab » and « rugged».

The distance from the nest or from the track's summit to the highest line of the tide is measured using a double decametre. Furthermore, in order to know the total distance of the egg-laying beach, we measure the distance from the first line of vegetation to the highest tide's line.

- ✓ **Marking the diggings and recording the nests:** when new diggings are observed, iron stick is driven into the sand as a mark, 1m behind the potential incubation chamber, in order to avoid hindering the access of emerging turtles to the beach. The main cavity (the one containing the eggs or, if the presence of eggs is uncertain, the last cavity before the descent) is called a "nest" and assigned a number.

2. Nocturnal prospection on Onetahi

Given the great amount of turtle ascensions observed since the beginning of the season, and thanks to the great accessibility of observation sites, facilitated by the implementation of a permanent field team on the Onetahi *motu*, nocturnal prospection on Onetahi has been systematic (5 times per night, each night). Five patrols were carried out at fixed hours: 20h30 / 22h / 23h30 / 1h00 / 3h00. The association Te mana o te moana's field teams were aided by volunteers of the hotel and by the staff from the security company of The Brando Hotel. When it came to handling the turtles, each person involved had received training and was accompanied by the staff of Te mana o te moana.

During patrols, field teams cover the coast to identify female green sea turtles in their ascending or egg-laying phase. If the turtle has already returned to the water and hence, has failed, the same protocol applies as during nocturnal prospection. However, if the turtle is still present on-site, in addition to gathering the aforementioned information, the following protocol applies:

- ✓ **Taking photographs of the animal:** each turtle has a unique layout of scales on its head profiles (Schofield et al., 2008), which is an exceptional tool for photo-identification (classified in the TORSOOI data base). De facto, a picture of both head profiles is taken, when encountering a turtle, as well as a general picture of the body. In order to better respect the animal, it is preferable to take pictures without flash and to use a red light.

- ✓ **Measures:** the length and curved width of the shell (CCL and CCW) are written down.

- ✓ **Ringing:** the turtles are ringed at the edge of the front flippers, between the two first scales. The rings are "Monel Tag", numbered on one side and provided by the Direction for the Environment in French Polynesia.

- ✓ **Genetics:** a skin sample is taken from the hind flippers' area for genetic analyses, led by the Direction for the Environment.

- ✓ **Epibionts:** in some cases, diatom samples are taken from the female turtle's shell for the research led by Catherine Gobin at the CRIOBE.

- ✓ **Other:** all details observed regarding the animal are meticulously written down, such as physical injuries on the body or a specific attitude of the animal towards external factors (hotel constructions, light, surrounding people, etc.…).

- ✓ **Nest protection:** when the turtle gets back to the lagoon and if the event led to the laying of eggs, solely in the case of Onetahi, a grid is set up to protect the active nest. Due to the implementation of The Brando Hotel, and despite the fact that a specific lighting policy has been put in place during the nesting period, negative effects of disorientation have been noticed numerous times amongst emerging turtles, when exiting the nest. To minimise the impact, the decision was made to set up a circular grid around the nest, during the entire incubation time period. These protections have proved efficient in many ways. They ensure a precise identification of nesting cavities, enable us to watch out for potential predators, and help us observe the emergence of turtles and their descent to the lagoon.

- ✓ Patrols are carried out to observe the emergence of turtles. Teams will either let them descend to the lagoon naturally or they will decide to bring them to a protected area, away from the artificial lights, and from there, let them get to the lagoon in the most natural way as can be. Active protection has enabled us to meticulously observe emerging turtles, their health condition and their energy. Our presence has played a big part in fighting off predators in the sand and on the beach, when they descend to the lagoon (birds, crabs, hermit crabs…).

Rules concerning the behaviour to adopt are very strict and need to be respected, when it comes to approaching and handling laying females. All handlings take place either after the turtle has laid its eggs or during the animal's descent to the lagoon.

3. Nocturnal prospection on other *motu* (Tiaraunu and Horoatera)

Besides daily nocturnal monitoring on Onetahi, near daily night watches take place on the Tiaraunu *motu* and regularly take place on the Horoatera *motu*. In the course of these expeditions, field teams follow the exact same protocol as the one carried out on Onetahi, apart from the nest protection phase, which is not applied on other *motu*. Teams benefitted from basic on-site camping structures.

4. Protocol used during the hatching phase on Onetahi and the other *motu*

Upon the discovery of an active nest, the estimated egg-laying date is determined. Based on previous years' collected data, the incubation time period of green sea turtle eggs on Tetiaroa was estimated between 50 and 80 days. Nest monitoring starts at this time, in anticipation of the emerging turtles. On the Onetahi *motu*, during the hatching time period and due to the protecting grids, the field team carries out a minimum of 2 to 4 patrols per night. The first one takes place at 20h30 and the last one at 5h, before the sun rises. Monitoring enables to observe the emergence of all protected nests on Onetahi.

After the main phase of emergence, a minimum of a two-day time period of animal security is respected. Following this time period, field teams dig up the nest to obtain precious information, regarding the hatching success rate, and intervene on weakened, deformed or emerging turtles, which are stuck, and unable to leave the nest. If no sign of emerging turtles is detected during the monitoring phase, the nest is dug up following the theoretically maximum amount of time, wherein the hatching should take place (+ 80 days).

If an incubation chamber and shells are discovered, the following measures are taken:

- ✓ **General information:** the date, hour, as well as the nest's number are written down

- ✓ **Counting the number of emerging turtles, which reached the surface:** when a hatched clutch is discovered, the number of emerging turtles is written down. We check each individual's energy in the umbilical area and if need be, assistance is brought to the juveniles, stragglers and wounded turtles.

- ✓ **Counting the eggs:** once the nest is excavated (minimum 48h after the hatching phase), the number of empty shells and the number of unhatched eggs are both written down. It is important to check the inside of unhatched eggs, in order to distinguish infertile eggs, from non-fertilised eggs and embryos, which died in the course of their development. We also take note of the number of deaths among the emerging turtles, which managed to exit the egg, and the number of live, emerging turtles, which could not get out of the nest.

- ✓ **Measures:** once the nest has been excavated, the maximum depth of the incubation chamber is measured (by hand, with gloves or using a small garden shovel).

- ✓ **Genetics:** in order to be able to proceed to genetic analyses, a skin sample is collected at the level of the emerging turtles' flippers, from dead individuals only (embryos or emerging turtles).

- ✓ **Predation:** observing and counting the predators in and around the nest. An infrared video camera was set up a number of times on the Tirana *motu*, in order to watch the behaviour of predators, when the emergence was occurring without the presence of field teams.

Results

I. Evolution of the egg-laying seasons since 2007

Along the years, the monitoring program of green sea turtles on Tetiaroa initiated by the association Te mana o te moana has gathered 11 seasons' worth of data. Regular monitoring has enabled the acquisition of precious information regarding the evolution of their presence on the atoll with the passing of seasons.

1. Phenology of egg-laying events

In French Polynesia, the green sea turtle egg-laying season runs from November until April (Lebeau, 1985). When taking into account the egg-laying phenology of the last eleven seasons on Tetiaroa, one can notice great differences between the time at which the season begins and ends, the length of the nesting season, as well as the length and time period, wherein the nesting peak occurs (Figure 3).

Despite this striking variety, its has also been noticed that increasingly, nesting seasons have been starting earlier and earlier, since the first monitoring operations, which took place in 2007: from November 5th in 2007 to July 12th in 2017, which amounts to a near 4 months' difference.

Also, the length of nesting seasons has changed greatly, from 156 days in 2007-2008 to 289 days in 2017-2018. With the passing of years, it seems that the nesting season has lengthened.

Likewise, the time of the nesting peak has changed. The latter is defined as the time period, in which the most nesting events have been observed. In 2007 and 2008, it used to take place around the months of January and February. Now and since 2009-2010, it draws towards the months of November, December and January. In the last four seasons, it seems to have been remaining so (Figure 3).

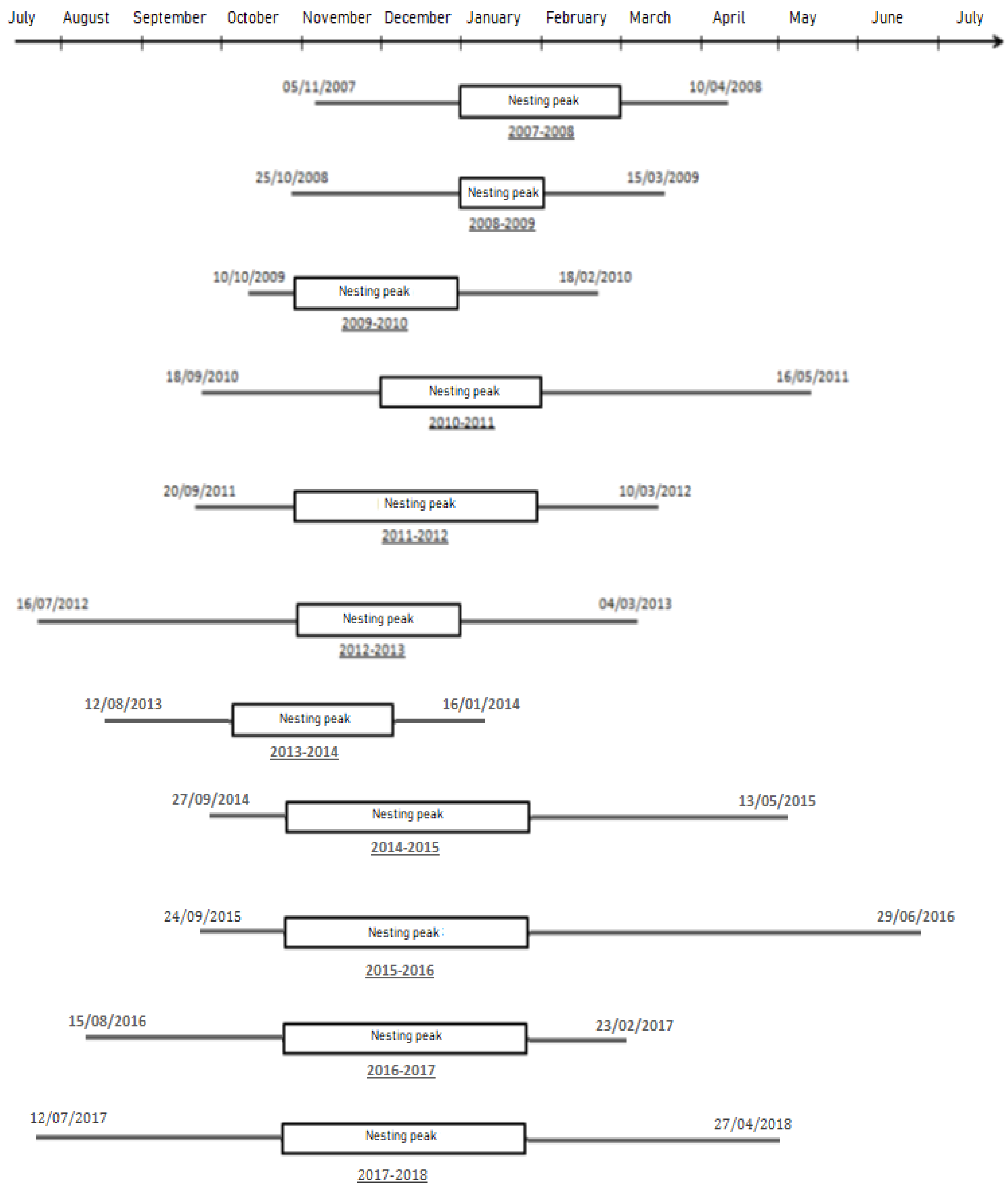


Figure 3: Spread of the nesting seasons from 2007 until 2018

2. Number of egg-laying events

The number of egg-laying events is also very heterogeneous and varies depending on the egg-laying season, from 53 ascensions during the 2009-2010 season to 1316 during the 2017-2018 season (Figure 4).

However, thanks to eleven years' worth of collected data regarding turtle nesting on Tetiaroa, the profile of a **three-year nesting cycle** seems to be shaping up. From the 2009-2010 season until the 2011-2012 season, an increased growth in the number of tracks has been observed. The same pattern has been observed from 2012 until 2015 and from 2015 until 2018.

In the following years, it will be possible to confirm the length of the nesting cycle, by recapturing the female in question, which will either be identified thanks to her rings or via the photo-identification of both her head profiles.

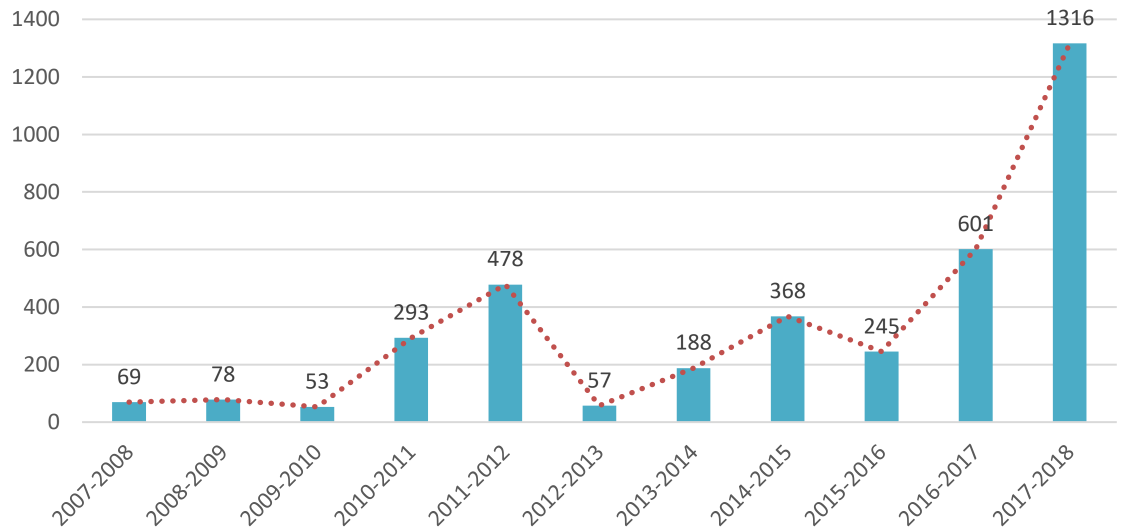


Figure 4: Evolution of the number of nesting events from 2007 until 2018

II. 2017-2018 season

1. Prospection efforts

The prospection was led from September 15th 2017 until June 4th 2018, which corresponds to **289 day patrols** on the 12 *motu* and **343 night patrols (**Table 1**)**.

On account of The Brando Hotel's implementation on Onetahi, which made its access easier, the number of patrols carried-out on the *motu* increased to a number of 5 per day (20h30 / 22h / 23h30 / 1h / 3h / 5h). The Tiaraunuu and Horoatera *motu*, known to preferably welcome the green sea turtles' nesting events on Tetiaroa (Petit et al. 2013), were regularly prospected during the day, at least twice a week, but also at night (73 night patrols on Tiaraunu and 6 nights spent on Horoatera). Regarding the 9 remaining *motu*, Honuea, Rimatu'u, Tahuna Rahi, Tahuna iti, Reiono, Aie, Tauvini, Auroa and Hiraanae, nearly each of these were kept under surveillance on average twice a month, except for the 3 last ones, which were only once visited due to the absence of green sea turtle tracks.

In total and throughout the entire atoll, teams covered more than **3 305 km** (Table 1).

Table 1: Prospection efforts during the 2017-2018 season

	Daytime prospection	Nocturnal prospection	Prospection efforts *(km)*
TIARAUNU	90	73	1180
HOROATERA	50	6	248
ONETAHI	35	264	1619
AUTRES	114	0	258,3
TOTAL	289	343	3305,3

2. Egg-laying events

2.1.Type of recorded tracks

1316 ascensions were identified during the 2017-2018 nesting season, on the Tetiaroa atoll. 690 unsuccessful attempts at laying eggs were found (among which feature 210 simple tracks (T) and 480 abandoned cavities (TN0)), which represent 52% of the total number of events. 629 egg-laying events were recorded. Out of the number of egg-laying events, **503 were proven true** (TN3 – the egg-laying was witnessed or the nests were excavated and the eggs counted), which amounts to 38% of events, and 123 remained a hypothesis (the presence of eggs in the nest wasn't confirmed (TN2 and TN1)), accounting for 10% (Figure 5).

Table 2 : Number of tracks

	TOTAL	PERCENTAGE
T	206	16%
TN0	484	37%
TN1	24	2%
TN2	99	8%
TN3	503	38%
TOTAL	1316	100%

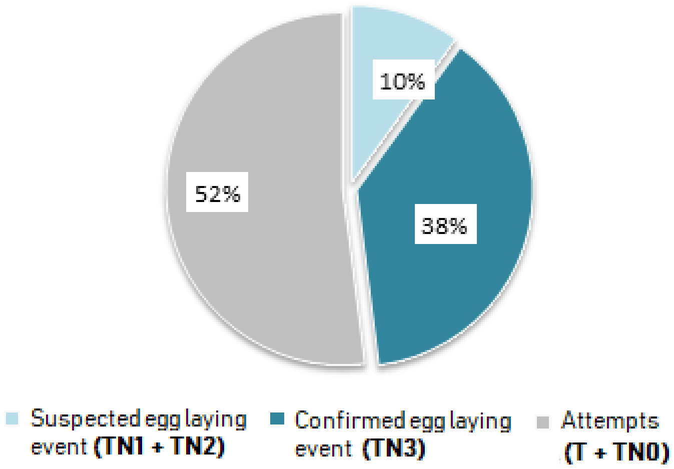


Figure 5: Type of recorded ascensions during the 2017-2018 season

2.2.Temporal distribution

Egg-laying events occurred between July 12th 2017 (estimated date of the first ascension) and April 27th 2018 (estimated date of the last ascension), in the course of **289 days**. This season, not unlike previous years, we can safely say that **the egg-laying peak occurred from November until January**, based on the fact that 79% of egg-laying events this year took place during this time period (Figure 6).

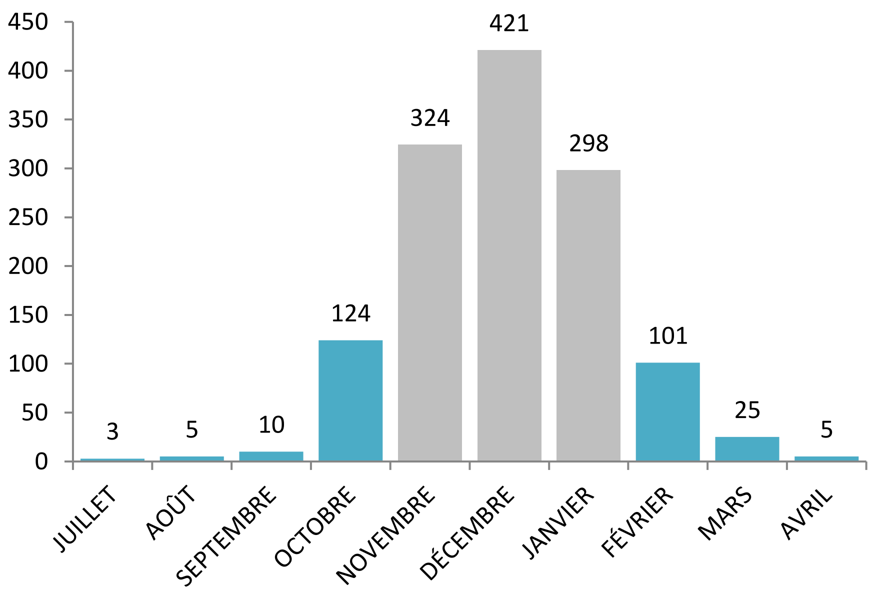


Figure 6: Temporal distribution of egg-laying events during the 2017-2018 season

2.3.Spatial distribution

The 3 main egg-laying areas of this season, which **accounted for more than 93% of events**, were found on the two great *motu* in the north, **Horoatera and Tiaraunu**, and on **Onetahi**. These sites had already stuck out in the course of previous seasons, as being areas with regular and high presence of green sea turtles, when compared to the rest of Tetiaroa.

This season, the presence of sea turtles on Honuea, Tahuna Rahi, Rimatuu, Tahuna iti, Reiono and Aie's has been relatively low, accounting for only 7% of events.

Not a single egg-laying event took place on Tauvini, Auroa and Hiraanae (Figure 7).

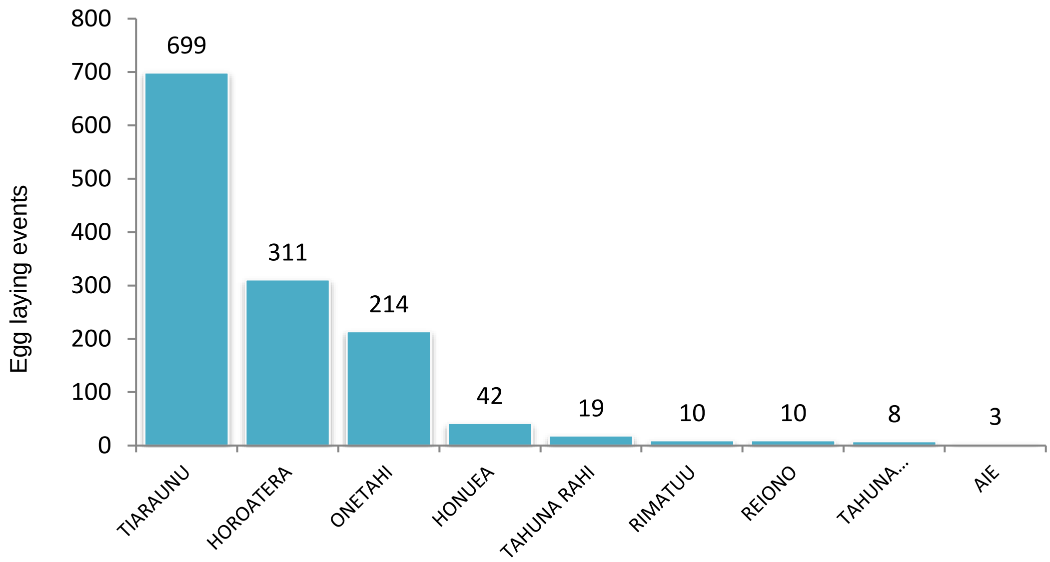


Figure 7: Number of recorded egg-laying events per motu during the 2017-2018 season

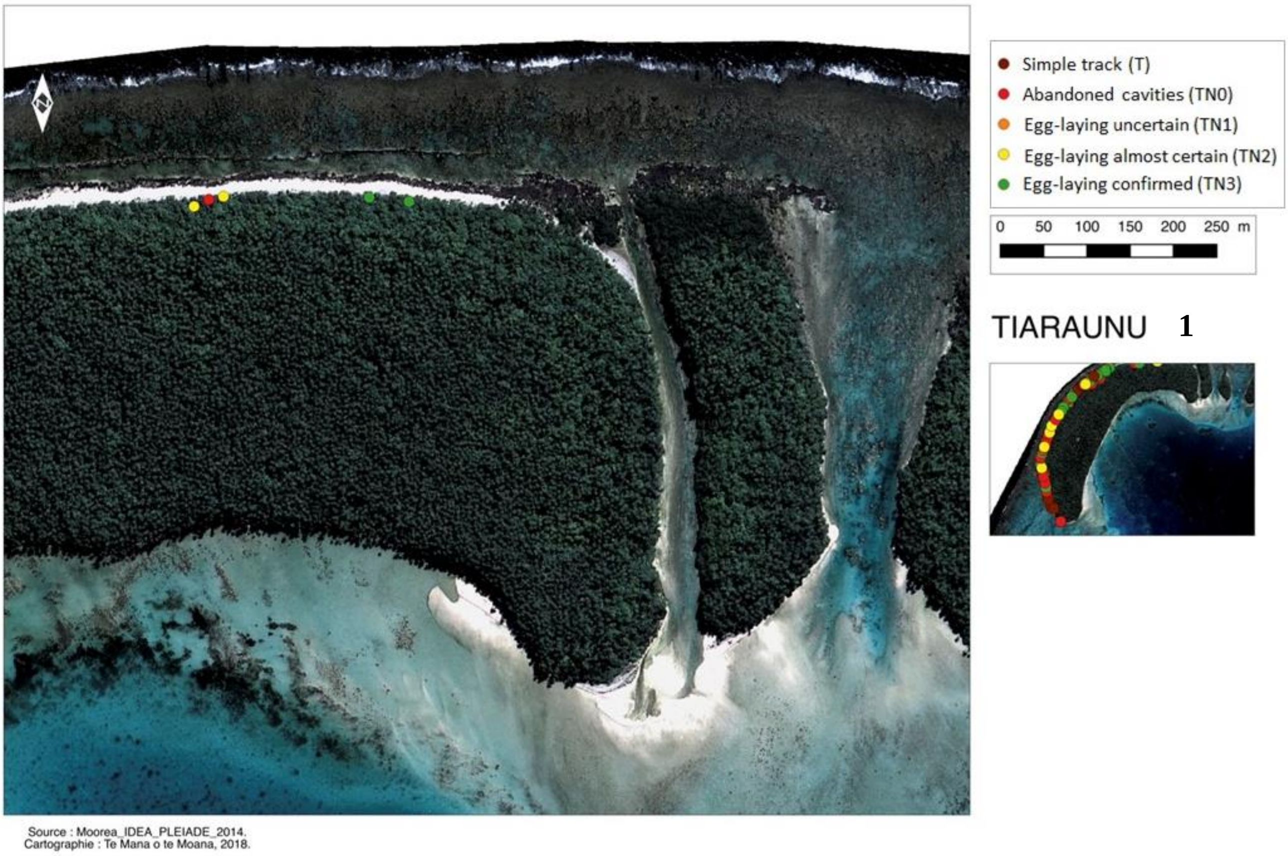
We will now be going into greater detail by discussing the case of each *motu* one by one, whereon there has been a more or less significant presence of sea turtles, by focusing on the different kinds of tracks discovered and the location of egg-laying events:

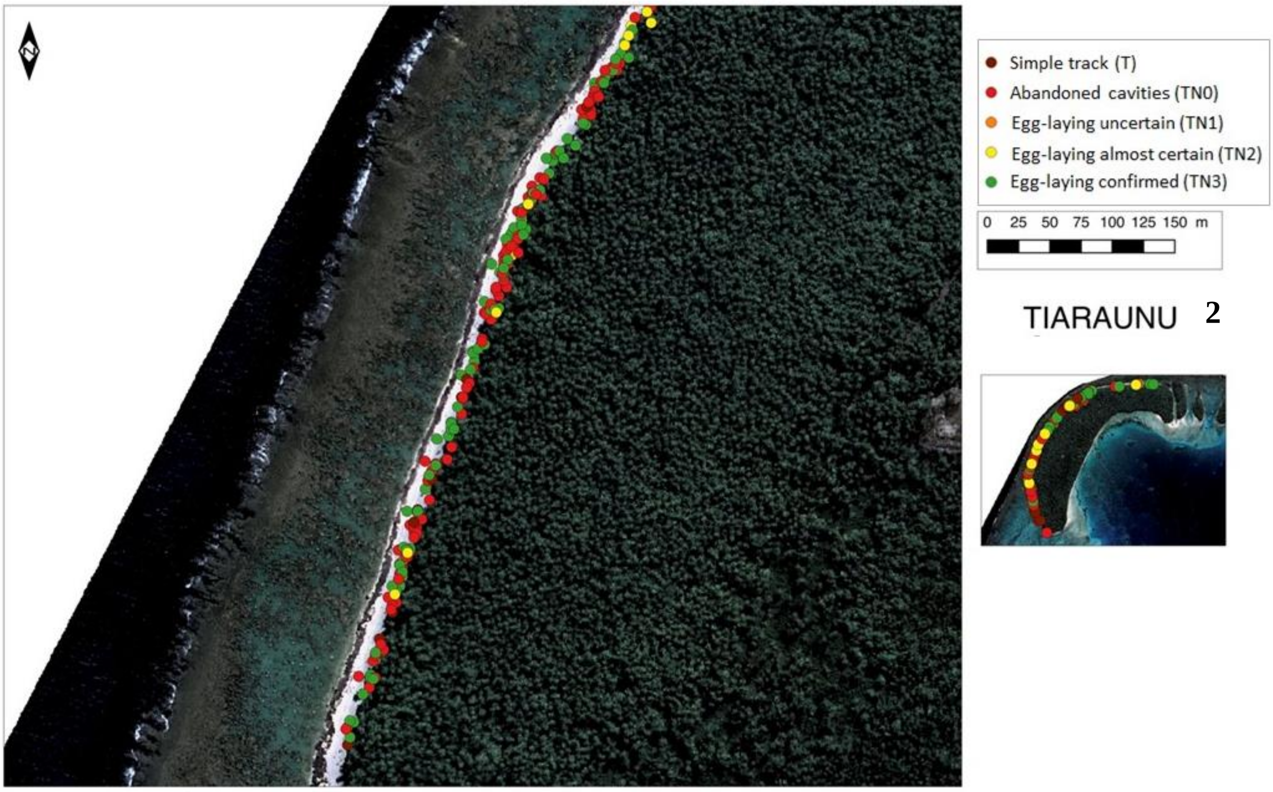
- **TIARAUNU**

The Tiaraunu *motu* accounted for **699 egg-laying events**. The egg-laying events were broken down as follows: 323 egg-laying confirmed (TN3), 29 egg-laying almost certain (TN2), 2 egg-laying uncertain, 282 unfinished nest digging attempts (TN0) and 63 simple ascensions & descents (T) (Table 3, Figure 8).

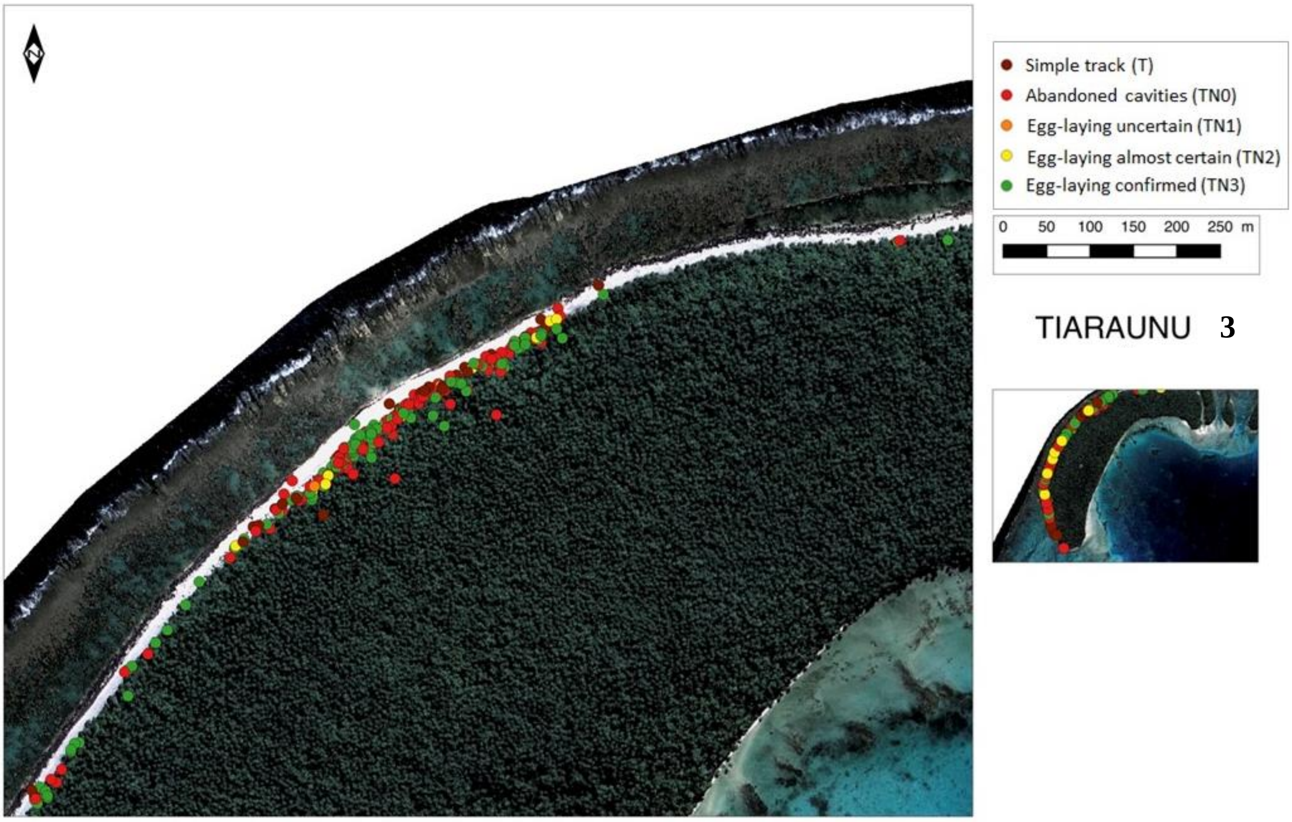
Table 3: Summary of egg-laying events on the Tiaraunu motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	323	29	2	282	63	699
PERCENTAGE	46%	4%	0%	40%	9%	100%





Source : Moorea_IDEA_PLEIADE_2014.
Cartographie : Te Mana o te Moana, 2018.



Source : Moorea_IDEA_PLEIADE_2014.
Cartographie : Te Mana o te Moana, 2018.

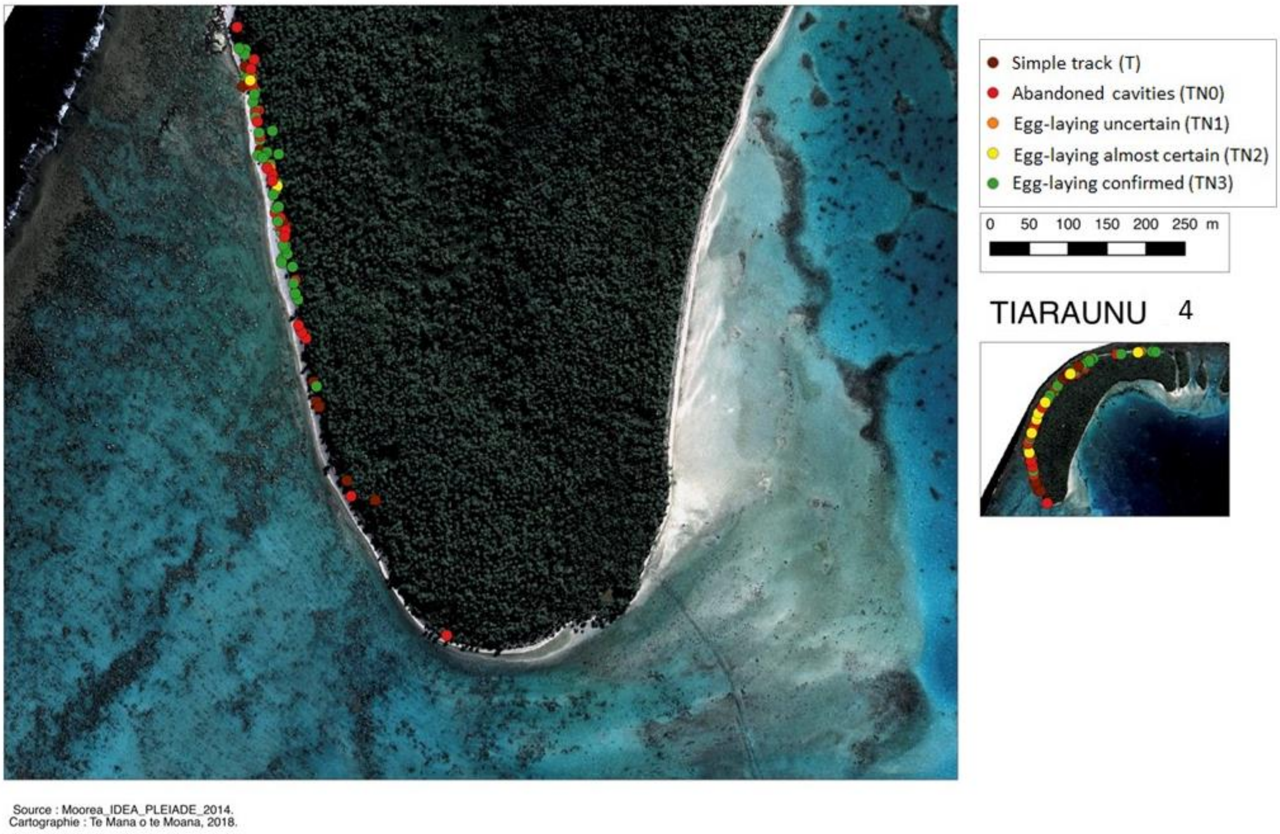


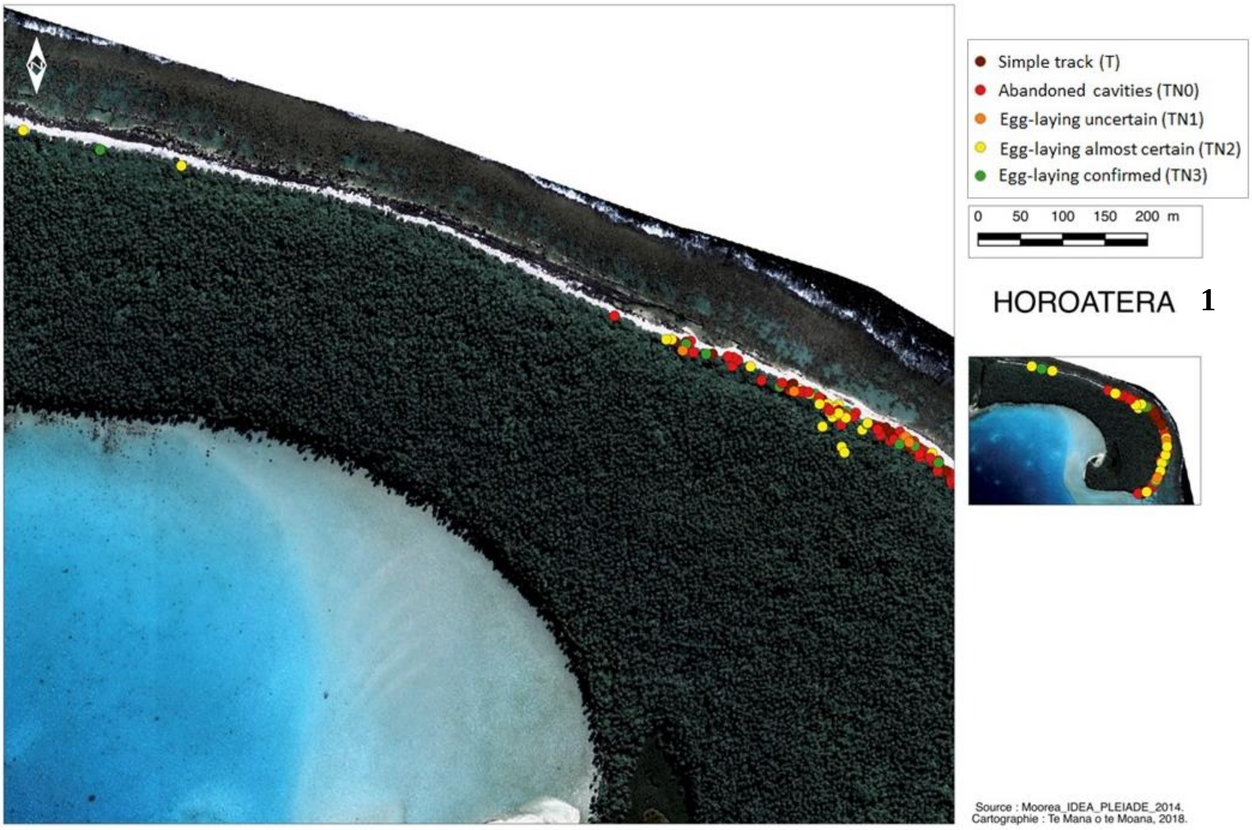
Figure 8: Cartography of green sea turtle egg-laying events on the Tiaraunu motu

- **HOROATERA**

311 egg-laying events took place on the Horoatera *motu*. The egg-laying events were broken down as follows: 55 egg-laying confirmed (TN3), 52 egg-laying almost certain (TN2), 15 egg-laying uncertain (TN1), 115 unfinished nest digging attempts (TN0) and 74 simple ascensions and descents (T) (Table 4, Figure 9).

Table 4: Summary of egg-laying events on the Horoatera motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	55	52	15	115	74	311
PERCENTAGE	18%	17%	5%	37%	23%	100%



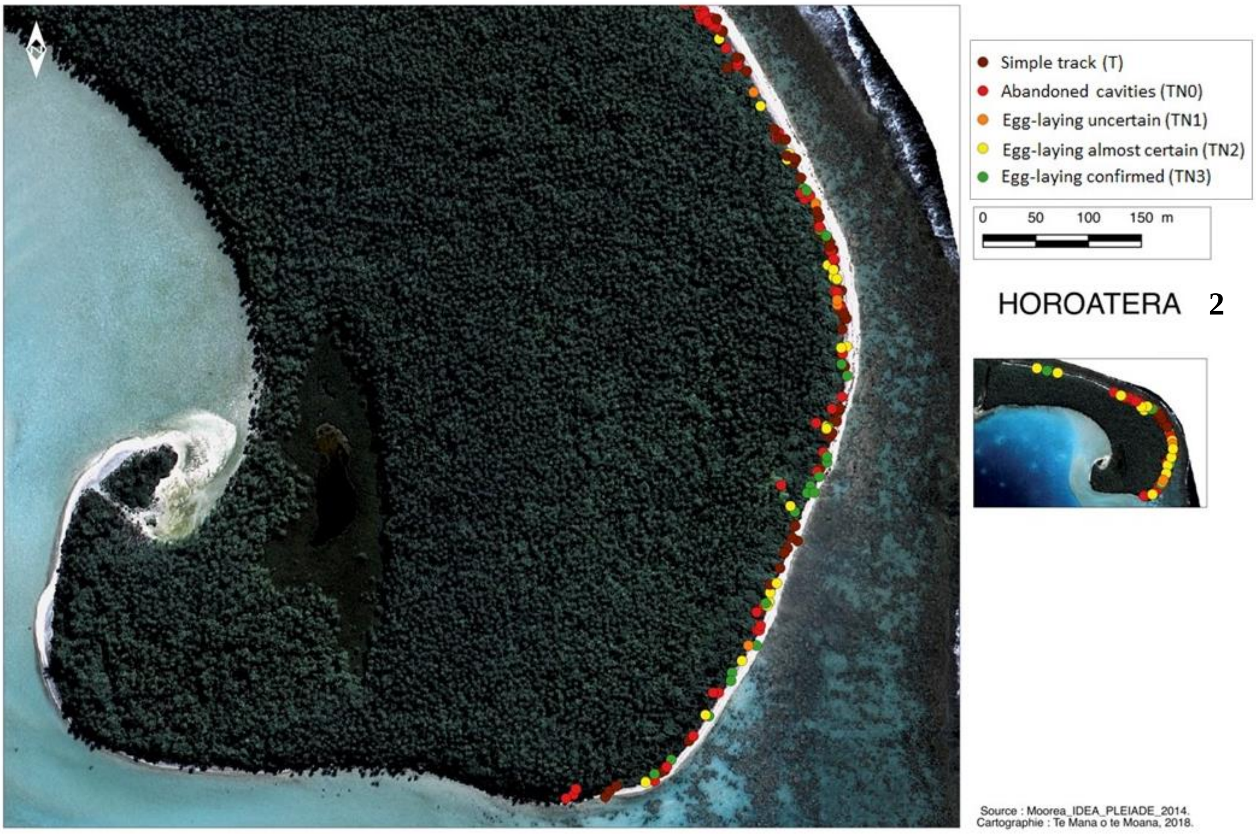


Figure 9: Cartography of green sea turtle egg-laying events on the Horoatera motu

- **ONETAHI**

On the Onetahi *motu*, field teams counted **214 egg-laying events**. The egg-laying events were broken down as follows: 101 egg-laying confirmed (TN3), 2 egg-laying almost certain (TN2), 53 unfinished nest digging attempts (TN0) and 58 simple ascensions and descents (T) (Table 5, Figure 10).

Table 4: Egg-laying events' summary on the Onetahi motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	101	2	0	53	58	214
PERCENTAGE	47%	1%	0%	25%	27%	100%

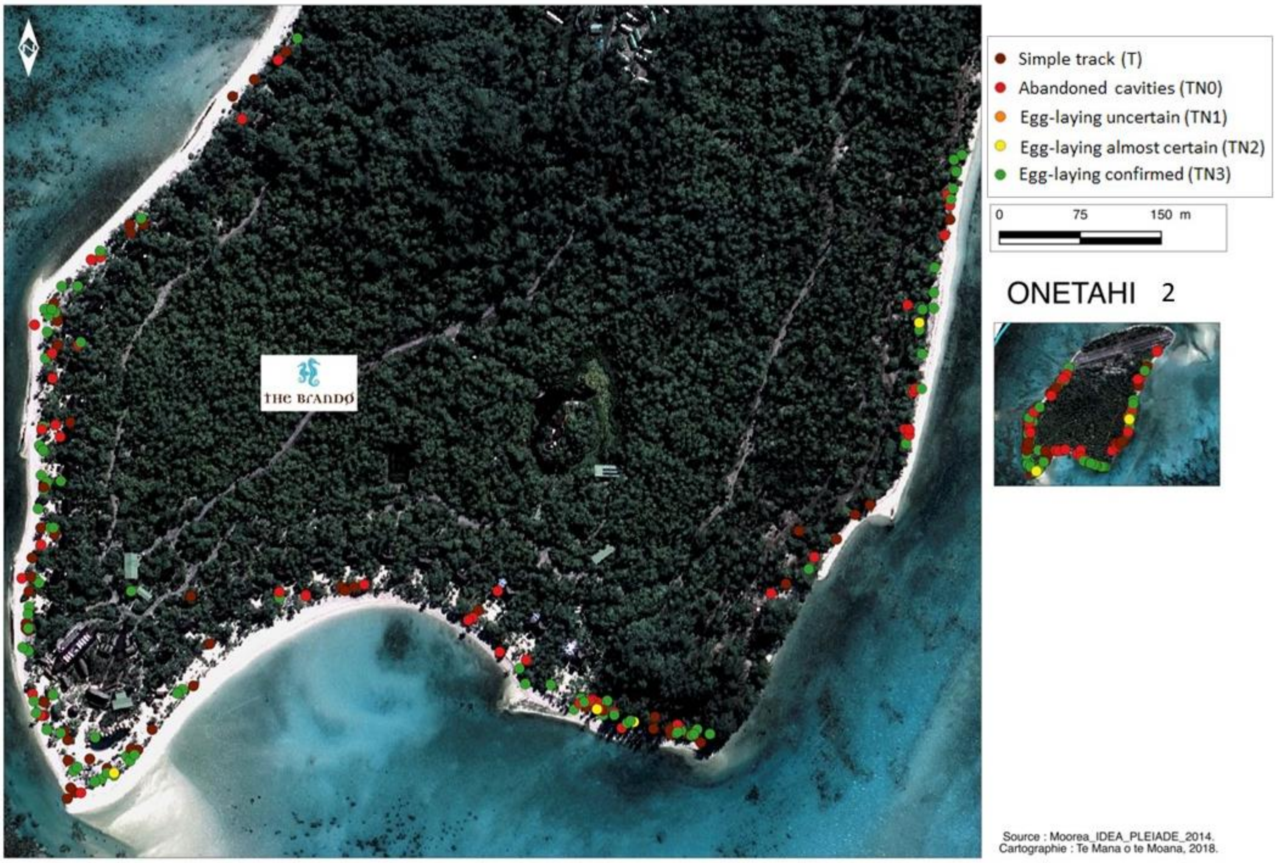


Figure 10: Cartography of green sea turtle egg-laying events on the Onetahi motu

- **HONUEA**

42 egg-laying events took place on the Honuea *motu*. The egg-laying events were broken down as follows: 15 egg-laying confirmed (TN3), 6 egg-laying almost certain (TN2), 2 egg-laying uncertain (TN1), 13 unfinished nest digging attempts (TN0) and 6 simple ascensions and descents (T) (Table 6, Figure 11).

Table 5: Egg-laying events' summary on the Honuea motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	15	6	2	13	6	42
PERCENTAGE	36%	14%	5%	31%	14%	100%

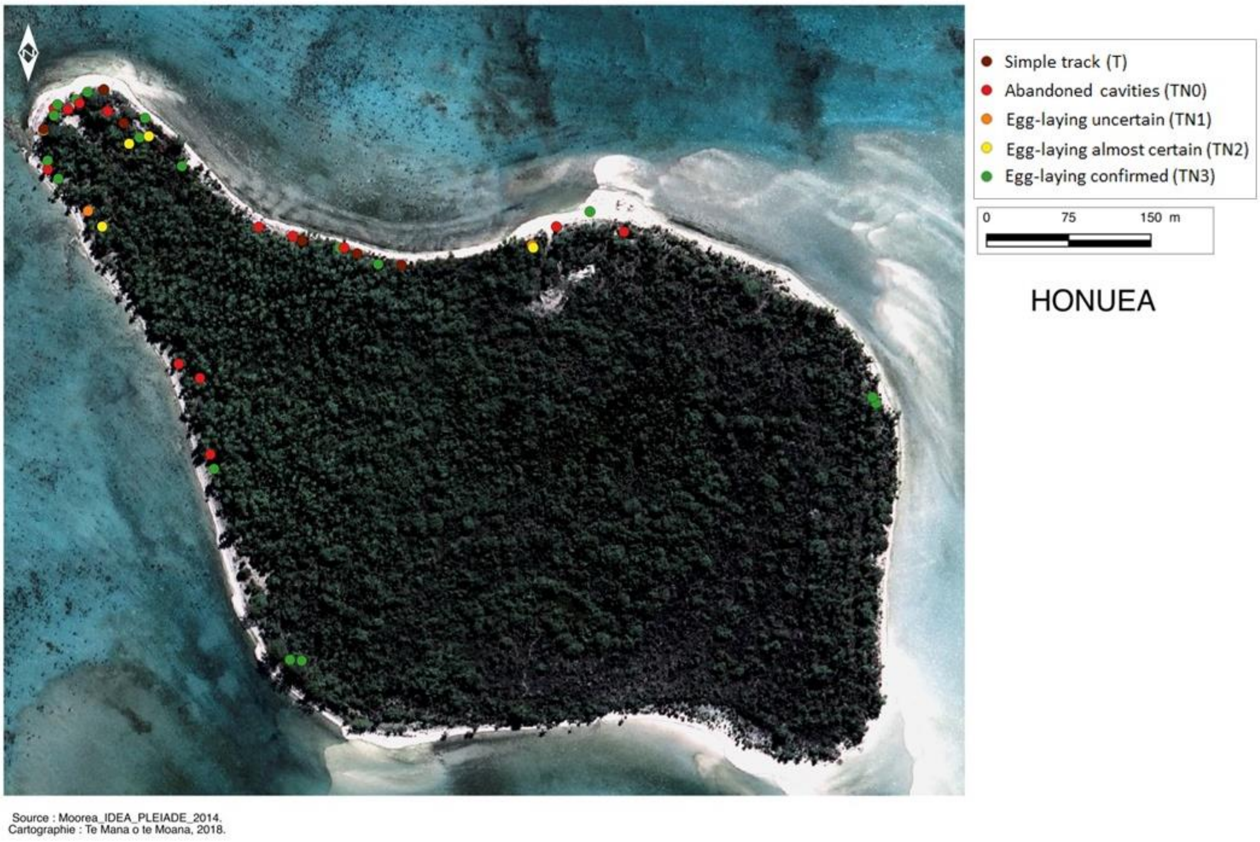


Figure 11: Cartography of green sea turtle egg-laying events on the Honuea motu

- **TAHUNA RAHI**

19 egg-laying events took place on the Tahuna *motu*. The egg-laying events were broken down as follows: 9 egg-laying almost certain (TN2), 4 egg-laying uncertain (TN1), 4 unfinished nest digging attempts (TN0) and 2 simple ascensions and descents (T) (Table 7, Figure 12).

Table 6: Egg-laying events' summary on the Tahuna Rahi motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	0	9	4	4	2	19
PERCENTAGE	0%	47%	21%	21%	11%	100%

Figure 12: Cartography of green sea turtle egg-laying events on the Tahuna Rahi motu

- **RIMATU'U**

10 egg-laying events took place on the Rimatu'u *motu*. The egg-laying events were broken down as follows: 3 egg-laying confirmed (TN3), 6 unfinished nest digging attempts (TN0) and 1 simple ascension and descent (T) (Table 8, Figure 13).

Table 7: Egg-laying events' summary on the Rimatu'u motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	3	0	0	6	1	10
PERCENTAGE	30%	0%	0%	60%	10%	100%

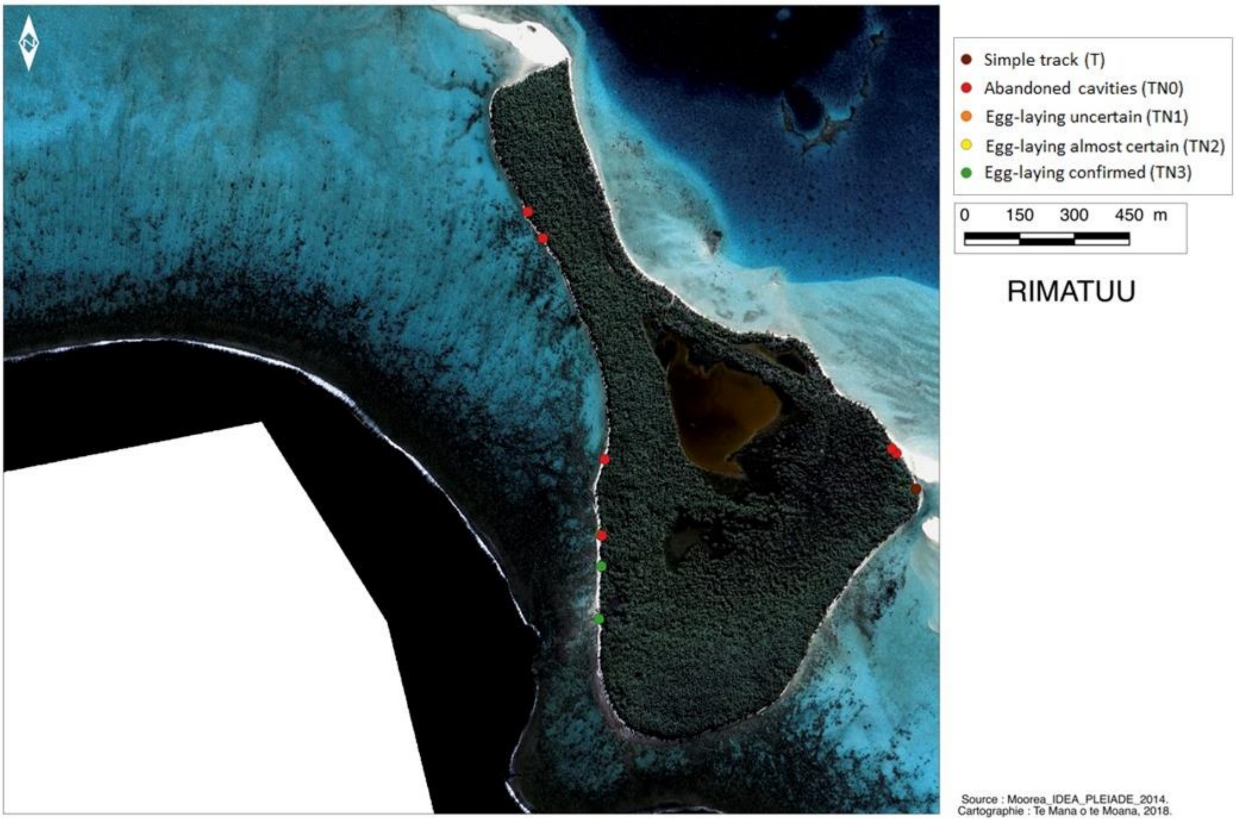


Figure 13: Cartography of green sea turtle egg-laying events on the Rimatu'u motu

- **REIONO**

10 egg-laying events took place on the Reiono *motu*. The egg-laying events were broken down as follows: 4 egg-laying confirmed (TN3), 5 unfinished nest digging attempts (TN0) and 1 simple ascension and descent (T) (Table 9, Figure 14).

Table 8: Egg-laying events summary on the Reiono motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	4	0	0	5	1	10
PERCENTAGE	40%	0%	5%	50%	10%	100%

Figure 14: Cartography of green sea turtle egg-laying events on the Reiono motu

- **TAHUNA ITI**

8 egg-laying events took place on the Tahuna Iti *motu*. The egg-laying events were broken down as follows: 1 egg-laying almost certain (TN2), 5 unfinished nest digging attempts (TN0) and 1 simple ascension and descent (T) (Table 10, Figure 15).

Table 9: Egg-laying events summary on the Tahuna Iti motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	0	1	1	5	1	8
PERCENTAGE	0%	12.5%	12.5%	62.5%	12.5%	100%

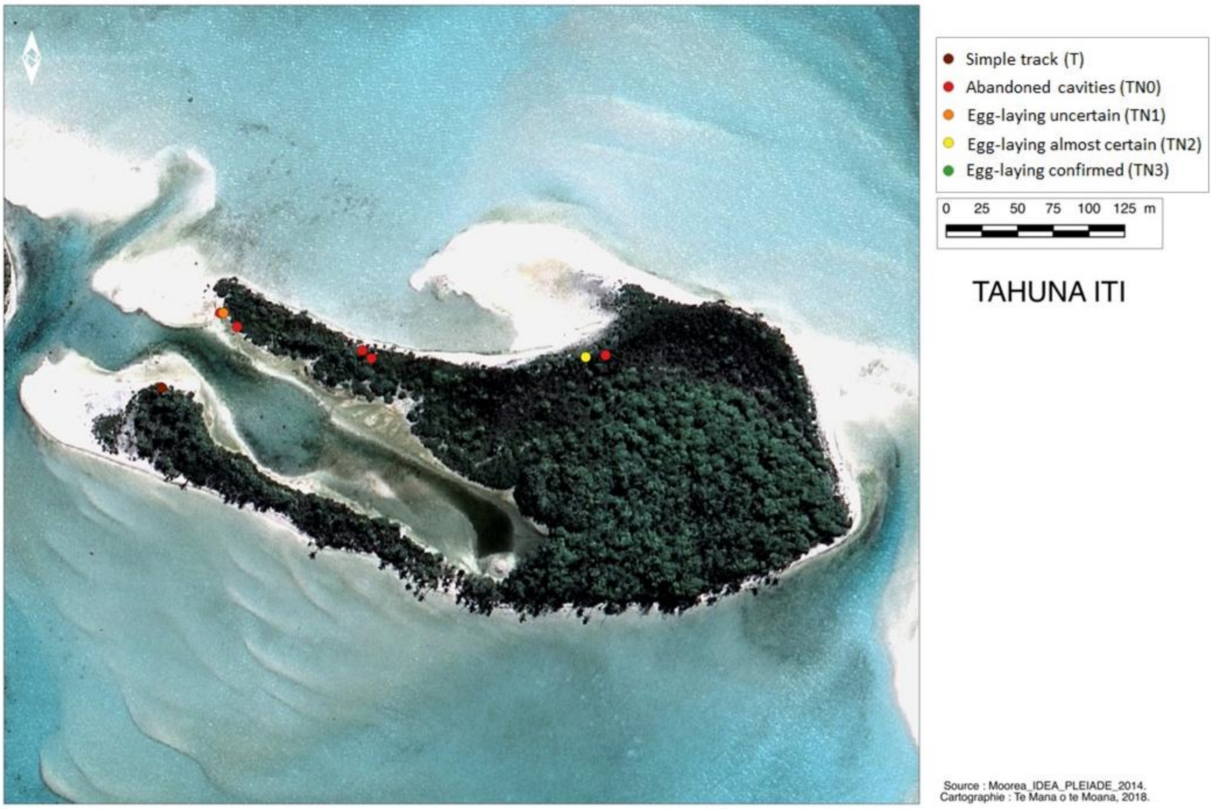


Figure 15: Cartography of green sea turtle egg-laying events on the Tahuna Iti motu

- **AIE**

3 egg-laying events took place on the Aie *motu*. The egg-laying events were broken down as follows: 2 egg-laying confirmed (TN3) and 1 unfinished nest digging attempts (TN0) (Table 11, Figure 16).

Table 10: Egg-laying events summary on the Aie motu

	TN3	TN2	TN1	TN0	T	TOTAL
NUMBER OF TRACKS	2	0	0	1	0	3
PERCENTAGE	67%	0%	0%	33%	0%	100%

Figure 16: Cartography of green sea turtle egg-laying events on the Aie motu

2.4. Influence of environmental factors

Out of the total amount of active nests, 50% were found in a “half-shaded” area, 25 % in the “shade” and 25% in “bright sunlight”. The Kruskal Wallis test showed that there exists a strong link between the nest's light exposure and the length of incubation (p-value = 0.0216). As a matter of fact, an active nest in the shade will have a tendency to have a longer incubation time period, than an active nest in bright sunlight.

35% of cavities were made in a “thin-crude” substrate, 32% in a “thin” substrate, 22% in a “medium-crude” substrate, 7% in a “crude” substrate, 2% in a “medium” substrate and less than 2% in a “medium-thin” substrate.

Finally, the analysis of the nest distance showed that 14% of nests were found amongst vegetation, 30% at the edge of vegetation and 56% at the back of the first line of vegetation.

The environmental factors, related to the “kind of substrate” and the “nest distance”, do not have any kind of influence on egg-laying parameters (Kruskal Wallis test).

Key numbers:

- **1 316 egg-laying events** were recorded, corresponding to **48 % of egg deposition** and **52% of digging attempts**
- The egg-laying peak occurs **between the months of November and January**
- Major egg-laying areas are located on the **Tiaraunu, Horoatera and Onetahi** *motu*

3. Females

3.1.Observations and identifications

During the 2017-2018 season, **396 female observations** occurred at night (32% of all recorded egg-laying events), 275 took place on Tiaraunu'u, 104 on Onetahi and 17 on Horoatera. Among these observations, field teams **witnessed 221 egg-laying events**: 152 on Tiaraunu'u, 64 on Onetahi and 5 on Horoatera.

Thanks to the Capture-Mark-Recapture method, **96 egg-laying females were identified**: 67 on Tiaraunu, 18 on Onetahi and 11 on Horoatera. Each individual's head profiles were photographed. 196 rings (Monel model of the DIREN, in big size) were set on the front flippers of 89 females. 30 rings had to be put back in place, as the former had quickly fallen from the turtles' flippers. Based on this discovery, 21 females were equipped with new rings of the DIREN's inconel model; none of these fell off. Genetic samples were collected from 78 females.

3.2.Egg-laying parameters

The average length of the shell is **100,4±2.9 cm** for an average width of **91.6±3.1cm** (Figure 17).

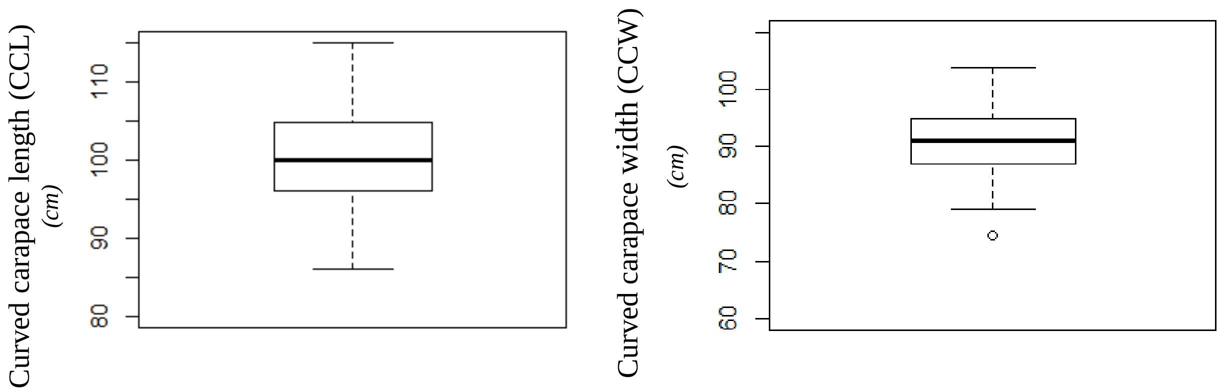


Figure 17: Distribution of the standard length of the curve (in centimeters) (on the left) and the standard width of the curve (in centimeters) (on the right) of the shell of female individuals during the 2017-2018 season

Before laying eggs, the female does on average **1.8 attempts.** On a sample of 453 nests, the minimum value observed equalled to 1 attempt and the maximum value to 9.

Upon the first ascension, the laying is not necessarily successful. Some females get back to the lagoon and come back to the beach in the following days at night to lay its eggs (after a maximum of 7 days). **If the turtle doesn't lay eggs during the first ascension, it will come back on average 1.3±0.6 days later.**

The egg-laying interval lasts an average of 13 days.

The egg-laying time period, that is to say the time between the first and the last contact, lasts about 73 days, in other words 2 months and a half. During this season, the longest egg-laying time period was 135 days, more than 4 months.

This season, it was estimated that each **turtle made an average of 6 nests**. This estimate is based on the observed nesting time period, divided by the average egg-laying interval (12 days).

On average, a **female green sea turtle spends 3h25 on the beach**. The time spent between exiting the water and when it starts laying its eggs (first laid eggs) lasts an average of 1h59. The act of laying the eggs (time between the first and the last fallen egg) lasts an average of 16 minutes. Covering the hole and returning to the lagoon takes the turtle about 1h20.

The rate of females returning to their nesting areas varies, due to the fact that their nests are hundreds of meters apart. This season, **7 females were seen in the act of laying eggs on 2 different *motu*** (Onetahi, Tiaraunu and Horoatera). Females do not keep to one only *motu*.

3.3. Comments regarding females

Figure 18: Photo reportage of the female Teiva stuck at the coral platform level, on the Tiaraunu motu

Assistance was brought to 8 females, who could not find their way back to the lagoon. Two of these got lost around The Brando Hotel, on the Onetahi *motu*. The remaining 5 were stuck on the Tiaraunu and Horoatera *motu* at coral platform level, which very uneven shoreline, hindered their return to the lagoon (Figure 18). Field teams intervened during the daytime, after having left females all night to attempt getting back to the lagoon on their own.

While observing females, field teams noticed that some of them had more or less deep wounds, mainly caused by poaching. As a matter of fact, 6 females presented harpoon holes either on the fins or on the dorsal part of their shell (Figure 19). Recapturing one of these wounded females 15 days after having observed it for the first time, enabled to witness the speed at which it healed - one of the species' characteristics (Figure 20). Moreover, certain females bore wounds at the neck level, a sign of more or less recent mating.

Figure 19: Photo-reportage of various females bearing harpoon wounds

Figure 20: Photo-reportage showing the healing process of a female's harpoon wounds recaptured 15 days later

Key numbers:

- **396 female observations** were realised
- **96 different females** were identified
- Females spend an average of **73 days on their egg-laying site** at Tetiaroa
- Females lay an average of **6 clutches per season with a 13 days interval**

4. Nests and emerging turtles

4.1. Nests

- Depth:

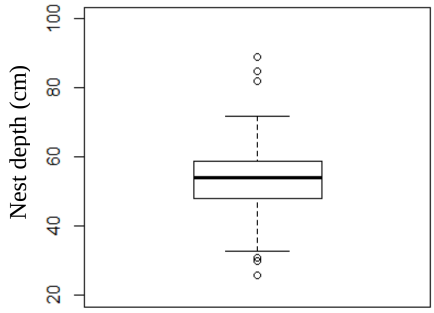


Figure 21: Depth of the excavated nests (in centimeters) during the 2017-2018 season

The maximum depth of nests (in other words the deepest emplacement of egg shells) is about 53,5±4,5cm. On a sample of 473 nests, the extreme values of this variable fluctuate from 26 cm to 89 cm (Figure 21).

The General Linear Model (GLM) enabled to demonstrate the significant influence of depth on the hatching success rate. When the nest is too shallow or too deep, success decreases. Hatching success reaches its peak (superior to 90%), when the nest is in a pit of medium depth, between 50 and 75 cm (Figure 22).

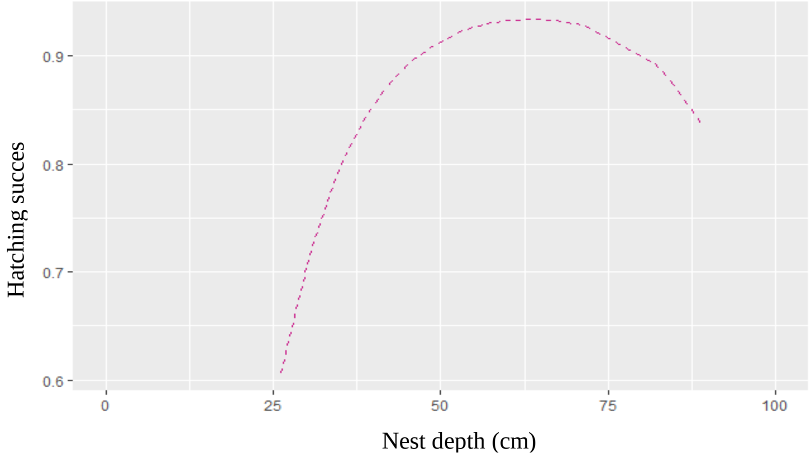


Figure 22: The evolution of hatching success correlated to the depth of the nests

- Number of eggs and hatching success

The nests contained an average of 86.4±9.9 **eggs**. On a sample of 477 nests, the minimum value observed is 6 eggs and the maximum value 144 eggs.

The average number of hatched eggs is 79±10.9 eggs/nest. Among the unhatched eggs featured an average of 0.3±0.1 infertile eggs, 3.5±4.2 non-fertilised eggs and 2.9±2.9 dead embryos.

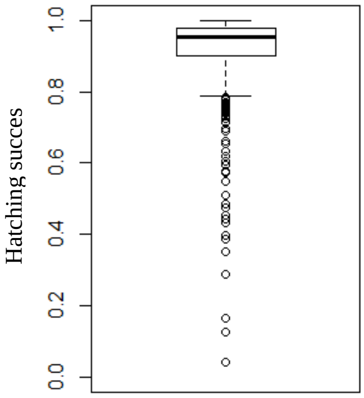


Figure 23: Distribution of the hatching success rate

Hence, on a sample of 477 nests, **the natural hatching success rate is 91**±1%. The minimum and maximum values are respectively 4% and 100% (Figure 23).

Field teams counted a total of **40 980 eggs on the entire atoll**, **of which 37 516 were empty shells**, in other words hatched eggs.

- Average incubation time period

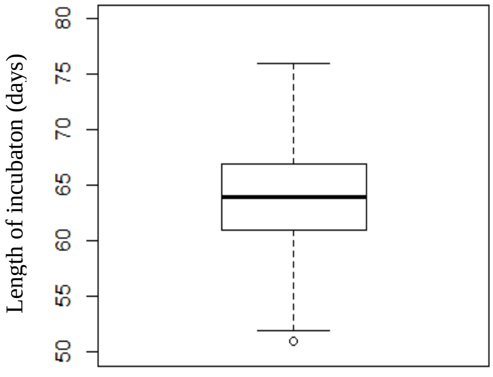


Figure 24: Distribution of the length of incubation (in days)

The estimated date, at which the eggs were laid and the hatching occurred, enabled to determine the average incubation time period with a varying degree of accuracy, depending on the nest. Thanks to patrols carried out on the Onetahi *motu*, it was possible to determine the exact hatching date of 73 nests. In the case of 358 nests, it was possible to estimate the date, at which the eggs were laid and the hatching had occurred, thus allowing to determine the incubation time period with enough accuracy. The **average time of incubation was 63.6**±2.4 days, **the minimum being 51 days and the maximum 76 days** (Figure 24).

- Relocated nests

This season, some nests had to be relocated due to their dangerous emplacement, which entailed high flood risks. In total, **7 nests were relocated**: 4 on Onetahi, 1 on Tiaraunu and 2 on Honuea. These relocations were only carried out, when the flood risk was too high. All relocated nests bore emerging turtles and a relatively high hatching success rate (Table 11). These were carried out based on the principle that the shorter the amount of time between the laying of the eggs and the relocation, the lesser the risks in terms of a fertilised egg's development. Thereby, to the extent possible, nests were relocated in a maximum of three hours after the eggs had been laid.

The below table is missing the fact that only 3 *motu* bore nests with high flood risks, but that these are the only 3 *motu*, where teams were able to notice the flood risk in a timely fashion. A few nests were flooded on the Horoatera *motu*. Field teams discovered this when excavating the nests after the hatching phase. They were unable to prevent this from happening, due to the insufficiently high frequency of interventions on this *motu*, cause by a lack of staff.

Table 2: Parameters of the relocations carried out during the 2017-2018 season

Motu	**Nest ID**	**Total nb of eggs**	**Nb hatched eggs**	**Hatching success**	**Relocation parameters**	**Comments**
Onetahi	One 73	70	70	100%	<3h after egg-laying	-
Onetahi	0ne 133	74	44	59,4%	27j after egg-laying	-
Onetahi	One 148	71	69	97,2%	<3h after egg-laying	-
Onetahi	One 159	94	90	95,7%	24 days after egg-laying	-
Tiaraunu	Tia 499	94	91	96,8%	<3h after egg-laying	-
Honuea	Honu 14	85	30	41,7	24h after egg-laying	Nests
Honuea	Honu 22	90	68	75,5%	48h after egg-laying	Flooded

4.2.Hatchlings

- Hatchlings observed at the surface

This season, on a total of 74 nests, **4 705 live hatchlings were observed at the surface**, the main part of which was observed live on the Onetahi *motu*. A few emerging turtles were observed on a deferred basis on the Tiaraunu *motu*, thanks to the installation of an infrared video camera.

- Hatchlings stuck in the nest

During the excavation of the nests, despite the fact that all eggs had hatched, **873 live hatchlings were found stuck in the nest** due to mechanical obstacles (root, coral…), or in a weakened or advanced dehydrated state with low chances of ever succeeding at getting out of the nest. Except for a few, all emerging turtles were saved and released in the lagoon. When turtles were found unable to swim well enough to reach the coral reef, they were brought to the laboratory of the Tetiaroa Society, in order to observe whether or not they would be able to recover. Those bearing signs of a worsening of their health condition were transferred to the Moorea care centre, to receive medical assistance, involving helping them to grow up to 30-40 cm of CCL, before releasing them in the ocean. Out of 873 emerging turtles, 23 were taken to the Moorea care centre.

- Embryos and hatchlings featuring anomalies

During the nest excavation phase, **1397 dead embryos** were found, some of which featured strong anomalies, such as malformations or pigmentary deficits (albinism). In total, 7 “albino” embryos were discovered: 2 on Onetahi, 3 on Tiaraunuu and 2 on Reiono, the majority of which bore strong deformations (single-eyed, headless, eyeless…). Field teams also found 7 twin embryos, 4 two-headed embryos and 2 embryos with a shell curved in reverse (Figure 25.

A few emerging turtles bore scale anomalies, but this didn't seem to affect their health condition. There were also 9 emerging turtles without back flippers (one of which is still alive and is being taken care of at the Moorea care centre (Minnie) (June 2018)) (Figure 25).

408 genetic samples were taken from emerging turtles and embryos. These samples were only collected from dead individuals.

Figure 25: Photo-reportage of the different anomalies observed in embryos and emerging turtles

- Predation

During this season, field teams witnessed acts of predation perpetrated by various predators on emerging turtles, whether it be earth predators (crabs of all kinds, hermit crabs, birds such as the greater crested tern) or sea predators (sharks and jack fish).

Video surveillance of nests located on Tiaraunu enabled to capture footage showing black rats (*Rattus rattus*) sniffing and digging nests in order to extract emerging turtles a few minutes before hatching. In total, 2 nests were filmed. Further videos demonstrated the strong presence of rats sniffing turtle nests many days before hatching, which shows rats' strong intent on finding turtles as soon as they emerge from the sand (figure 26).

Figure 26: Photo-reportage of predators attacking emerging turtles (hermit crab, ghost crab and black rat) observed on Tetiaroa

<u>Key numbers :</u>

- **40 980 eggs** were counted, included **37 516 hatched**
- Hatching succes is around **91%**
- **4 705 live hatchlings** were observed **at the surface**
- **873 live hatchlings** were found **stuck in their nest**

During the 2017-2018 season, 9 temperature probes were inserted in 19 “real nests”: 11 on Onetahi and 6 on Tiaraunu. The previous season (2016-2017), another 17 temperature probes had been installed in “fake nests”: 2 on Onetahi, 8 on Tiaraunu and 7 on Horoatera.

Data collected from the temperature probes is currently being analysed. The information, which will arise from this data, will contribute to the development of a vast research program focusing on the long-term evolution of sand temperatures, in the context of climatic change.

- **Satellite monitoring**

In partnership with the Direction for the environment, as well as the Fenua Geek Company, a female equipped with the ARGOS satellite beacon on December 14th 2017, has since then been the subject of regular observations carried out by field teams belonging to the Te mana o te moana association.

The female named Tia’turira’a (“hope” in Tahitian) measures 96 cm in length and 87 cm in width, when taking into account the shell's curve. She wears the ring “Tetiaroa 104” on the front flipper on the right side and “Tetiaroa 103” on the front flipper on the left side. In total, she was observed 9 times on the beaches of Tetiaroa, always on the Onetahi *motu*.

The following table shows the collected information related to each and every capture (Table 12):

Table 12: Egg-laying event parameters of the female Tia’turira’a

Date	Type of track	Number of eggs laid	Number of hatched eggs
07/11/2017	TN0	/	/
20/11/2017	T	/	/
23/11/2017	TN3	98	78
03/12/2017	TN3	83	80
14/12/2017	TN0	/	/
15/12/2017	TN0	/	/
27/12/2017	T	/	/
27/12/2017	T	/	/
28/12/2017	TN3	93	88

On May 12th 2018, after 139 days and having covered 1 890 km since the beacon had been equipped, the Tia'turira'a turtle still emitted and seemed, like all female turtles of Tetiaroa who had been equipped with beacons, to move towards the whereabouts of the Fiji Islands (Figure 27). The collected data of her movements is still being analysed and collected by the DIREN.

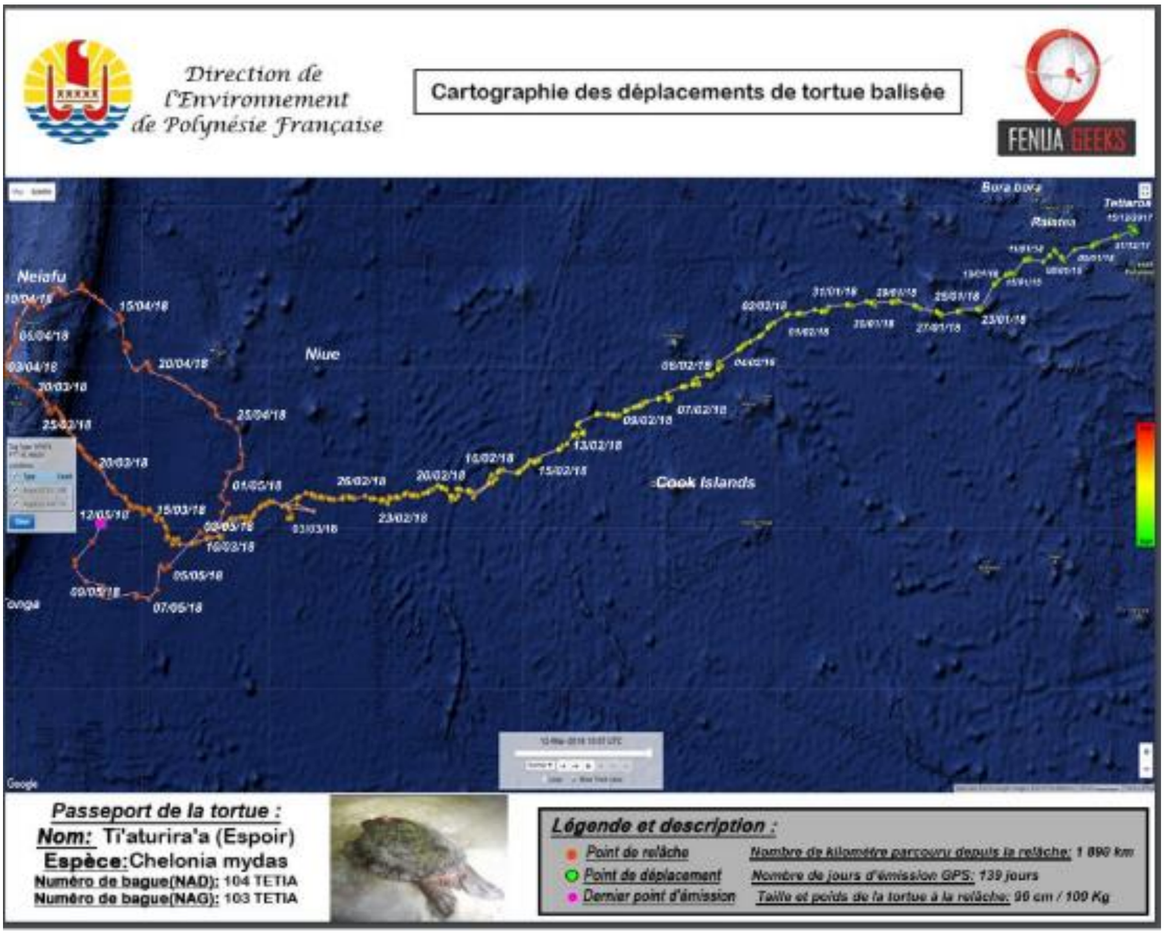


Figure 27: Cartography of the female Ti'aturira'a's movements

- **Epibionts**

Since the 2016-2017 season and in collaboration with Dr. Catherine GOBIN, a study has been being carried out based on microscopic samples of seaweed, taken from the dorsal part of the shell of *C.mydas* females.

During the 2017-2018 season, samples were taken from 8 different females.

The samples are currently being analysed.

- **Tide gauge and GPS system**

To improve the collection of satellite data, but also to know how the lagoon level is evolving, a differential GPS system (DGPS), as well as a tide gauge, were set up on the Tetiaroa atoll. The installation of the equipment was realised thanks to the collaboration of TMOTM and the Dutch company Van Oord, specialised in marine engineering. Their cutting-edge technology enabled the association's field teams to better evaluate risks related to rising waters and hence immediately adapt its conservation efforts (nest relocation…).

Discussion

1. Overall assessment

Taking into account 11 years of monitoring, the 2017-2018 egg-laying season seems to be record-breaking.

First, since the beginning of monitoring efforts, it has been the longest season recorded. In 2007, the season lasted 156 days, whereas this year it lasted an estimated 289 days. The egg-laying season has lengthened with the passing of time. Based on literature, the lengthening of egg-laying seasons often correlates the rising of ocean temperatures (Limpus and Nichols, 1986).

Second, the number of egg-laying episodes observed on the Tetiaroa atoll has been constantly increasing. When taking it from the perspective of the three year cycle of egg-laying, one can notice that egg-laying events recorded during the last cycle (from 2015 until 2018) have multiplied by three (perhaps 4), in comparison with the egg-laying events of the previous cycle (from 2012 until 2015). This increase cannot be explained by the intensification of prospection efforts, as even though sampling efforts were weaker between 2007 and 2014, only a few tracks could have gone unnoticed at that time, as prints remain visible for a long time (3 to 4 weeks depending on the conditions). This also explains, why only a little amount of tracks was reported every two weeks, when teams were visiting the sites. Furthermore, since 2014, teams of the Te mana o te moana association were present on the atoll on an almost permanent basis (since the opening of The Brando Hotel), and the number of tracks recorded during the 2014-2015 season is 3.5 times inferior to the number of tracks recorded during the 2017-2018 season. The hotel's presence, and thus, of all operating teams (Te mana o te moana, Tetiaroa Society, The Brando Hotel and its security company) seems to foster this increase. If in the past, Tetiaroa used to be an important poaching site aimed at the consumption of green turtle flesh (Petit et al., 2013), today thanks to the year long, daily presence of rangers from the Tetiaroa Society, and biologists of Te mana o te moana from October until June, fishermen and poachers have a harder time poaching without being noticed. Additionally, in recent years, the local government has strengthened the law by increasing the sentence (Environmental Code).

This massive increase in the number of egg-laying events could be the result of conservation and protection efforts realised on the Tetiaroa atoll. These efforts also had a nationwide effect, thanks to wide educational, awareness operations carried out on all archipelagos, and thanks to the creation of networks of " certified sea turtle from DIREN" trained by the DIREN.

2. Egg-laying events

This season, out of 1316 recorded egg-laying events, 48% were successful and 52% were attempts. The reason why females make so many egg-laying attempts, when they ascend a beach, is still fairly unknown. However seemingly, this fairly even distribution finds its coherence, when taking into consideration information found in literature concerning green turtles (Troeëng and Rankin, 2004).

On the other hand, a high amount of simple tracks (T) was found on Onetahi and Horoatera. In fact, if on most other motu of the atoll, the number of ascensions, which didn't feature any diggings, is always inferior to 15%, the latter accounts for respectively 27% and 23% of ascensions. To this day, interpreting these numbers is arduous. More data is needed to be able to formulate concrete hypotheses.

3. Female characteristics

Identifying females was enabled by two marking methods: flipper tags ("monel-inconel" ring model) and photo-identification. Concerning the former, this season, many tags fell off, which resulted in generating questions regarding the kind of tag that should be used. In order to minimise ring losses, it appears that the "inconel" tag model is best for ground monitoring (Balazs, 1982, Balazs, 1983). As for the latter, photo-identification is an innovative method, based on the specificity of scales located on a turtle's head profiles. Its efficiency as a monitoring method was confirmed and it can already be used in the juvenile phase (Carpentier et al. 2016). It is a reliable method for long term monitoring, which, paired with the ring marking system, will continue being used in the future.

In total, 96 females were identified. This season, given that our field teams could not be present on various *motu* during the night time, the population of adult females on the atoll has been estimated between 120 and 130 individuals.

Throughout the season, these females spent an average of 73 days in their reproduction area and laid an average of 6 clutches. These results seem much more superior to what has been observed in other regions of the world, with an average of 3 nests per season in the Mediterranean area (Broderick et al., 2002) and 2,8 in Costa Rica (Troeëng and Rankin, 2004). For the moment, this high egg-laying rate still cannot be explained and could be inherent to the green sea turtle population nesting on the atoll. Thus, pursuing monitoring efforts on a long-term basis is necessary.

4. Nest characteristics

Presently, there is few available information regarding green sea turtle general nest characteristics from French Polynesia. This year, on Tetiaroa, we have found an average of 86,3 eggs in active nests. Elsewhere worldwide, green turtles laid an average of one hundred eggs per nest (Waqas et al, 2011; Hamann et al, 2006; Aureggi, 2001). In some regions, the average is even higher, like in the case of the Tromelin and Glorioso Islands, where an average of respectively 136 and 135 eggs were laid with a maximum value of 191 (Vergonzanne et al., 1976). Even though the number of eggs produced is relatively low in comparison with the rest of the world, the Tetiaroa atoll has a very high hatching success rate, being superior to 90%. Numerous studies have recorded lower hatching success rates, for example 59% at Melbourne Beach in 1985 (Ehrhart et al., 1987), 80% on Surprise Island (Caut et al., 2007) and in 2007, during a mission at Tikehau in Polynesia, an average of only 51 to 77% (Albar, 2007).

5. Characteristics of emerging turtles

This year, an estimated 49 500 emerging turtles *Chelonia mydas* were born on the Tetiaroa atoll. This result, based on the number of hatched eggs, does not take into account the actual success rate of emerging turtles, given by the number of live emerging turtles divided by the total number of hatched eggs. The reason is that the latter was mainly impacted by ground predation (Ehrhart, 1987). On Tetiaroa, it is not easy to observe and quantify the impact of predation on emerging success. In fact, it is frequent for predators to extract emerging turtles from their nest before eating them (Dodd, 1988, Ali et al., 2002). This behaviour, common to crabs and other crustaceans, is also common to rats. Despite the fact that in the past, rat predation was considered negligible, when it came to emerging sea turtles (Vergonzanne et al, 1976), it is now considerable, reaching up to 45% of their diet (Caut et al., 2007). To this day, when monitoring green sea turtle egg-laying sites, this topic is not often taken into consideration. This year, thanks to the setting up of infrared video cameras to watch specific nests on the Tiaraunu *motu*, we could prove the presence of recurring black rat predation (*Rattus rattus*) on emerging turtles. The system of video cameras is an efficient means to observe this kind of predation. It has enabled us to take the decision of orienting our future efforts towards a better evaluation of the various impacts of predators on emerging turtles in the green sea turtle conservation program of Tetiaroa, and more specifically the impact of rats. A program of rat-disinfestation on one of the *motu* could emerge from this, with the support of the Tetiaroa Society.

Putting predation aside, the emerging success could be compromised by mechanical obstacles located in the nests, such as roots and stones, preventing the emerging turtles to get out of their nest. This year, during the nest excavation, 873 emerging turtles were found stuck in their nests by field teams of the Te mana o te moana association, the majority of which were saved in time and were immediately let go of, so that they could get to the ocean. Results point to the fact that excavating the nests, as fast as possible after the hatching phase, has highly contributed to conservation. As a matter of fact, it enabled nature to play its role in letting successful emerging turtles follow their path, but also enabled the emerging turtles, which encountered difficulties, to have a chance at life, by helping them just before they reached a state of advanced dehydration and the exhaustion of vitelline reserves.

Conclusions & Perspectives

These results once again demonstrate that the Tetiaroa atoll is one of French Polynesia's major green sea turtle egg-laying sites.

Egg-laying monitoring on the Tetiaroa atoll needs to continue in order to keep acquiring data regarding this emblematic species. In fact, 10 years of monitoring has brought us answers concerning the phenology of egg-laying events, as well as nest, track, emerging turtle and adult female characteristics. In the meantime, the acquisition of valuable information regarding temperatures, genetics and satellites is starting to take shape. Over the years, the accumulated data acquired through monitoring could very well increase our scientific knowledge of Tetiaroa's green sea turtles and thus, help us protect the species in French Polynesia on a wider scale.

To do so, leading targeted studies focusing on key elements of the species' life cycle would be essential. The priority projects would be the following:

- **Marine study (manta tow)**

Monitoring the marine life of turtles with the manta-tow method, adapted by the teams of Te mana o te moana, has already proved its worth in the domain of sea turtle research (Petit and Gaspar., 2011). This method enables to cover a wide distance over a short amount of time and hence, record a great number of individuals, during several seasonal around the same islands.

The execution of numerous follow-ups at sea, during the entire egg-laying season, would allow the acquisition of new information regarding Tetiaroa's adult green sea turtles, and especially adult breeding males, the latter which at this stage are not well known. Also, this kind of monitoring would permit to correlate the data discovered on the ground with the data at sea.

- **Study of male migration**

Further pursuing the objective of getting to know more about breeding males, it would be interesting to equip one or more of them with a transmitting satellite. In fact, setting up satellites on sea turtles is a scientific tool enabling to follow their movements and better understand the population's distribution and migration. On Tetiaroa, laying females' migratory journey between the reproduction area and the feeding area is well known. However, the breeding male's journey and its comings and goings during the breeding season, whether it be in the surroundings of the atoll or pretty much anywhere, remain a mystery.

- **Study of the sex-ratio and pivotal temperature**

In a context of climatic change, it becomes crucial to know the pivotal temperature influencing gender determination of green sea turtles on Tetiaroa. The latter has already been determined on many egg-laying sites and we know that there exist big differences from one site to the next (Refsnider, J.M., and Janzen, F.J., 2016). Studying the gender of emerging sea turtles does not require their killing anymore, thanks to new methods arisen in the 2000s, which have enabled to conduct research without hindering the species' conservation (Jensen et *al*., 2018).

Finding out the pivotal temperature on Tetiaroa's egg-laying site will finally allow us to give an accurate estimate of the *male/female* proportion of new-borns in the coming years. This also applies to all nests observed in previous years, wherein field teams inserted temperature probes (67 nests observed since 2011). From a conservation's perspective, this is an important matter. Australian researchers published their results in 2018 (Jensen et *al*., 2018), showing that egg-laying sites north of the great coral reef produced more than **99.1%** of females - a change observed in the last two decades. Such a high proportion presents a definite risk for the viability of the green turtle species.

- **Study of predation on emerging turtles:**

Monitoring the impacts of predation on all *motu* of the Tetiaroa atoll, especially Tiaraunu and Horoatera, appears to be paramount. This does not include the Onetahi *motu*, where emerging turtles are protected and where while being monitored, 100 % of the turtles with sufficient energy get to the lagoon with no risk of predation. This season, footage filmed by the infrared video cameras confirmed that the *Rattus rattus* rat is a definite predator for emerging turtles right from the moment they hatch. It has become highly necessary to evaluate their impact on the number of emerging turtles nested on the atoll, in order to determine the degree of emergency regarding the setting up of nest protection measures, or if need be, rat eradication measures. Presently, these measures seem to be the ones that would have the highest impact in terms of conservation and could, in addition to positive actions of protection performed on laying females, have the most crucial impact on emerging turtles and their survival rate on the beach before getting to the lagoon.

Put together, all these conservation actions without exception will have immediate or long-term fundamental consequences on the conservation and survival of the green sea turtle species on the Tetiaroa atoll.

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