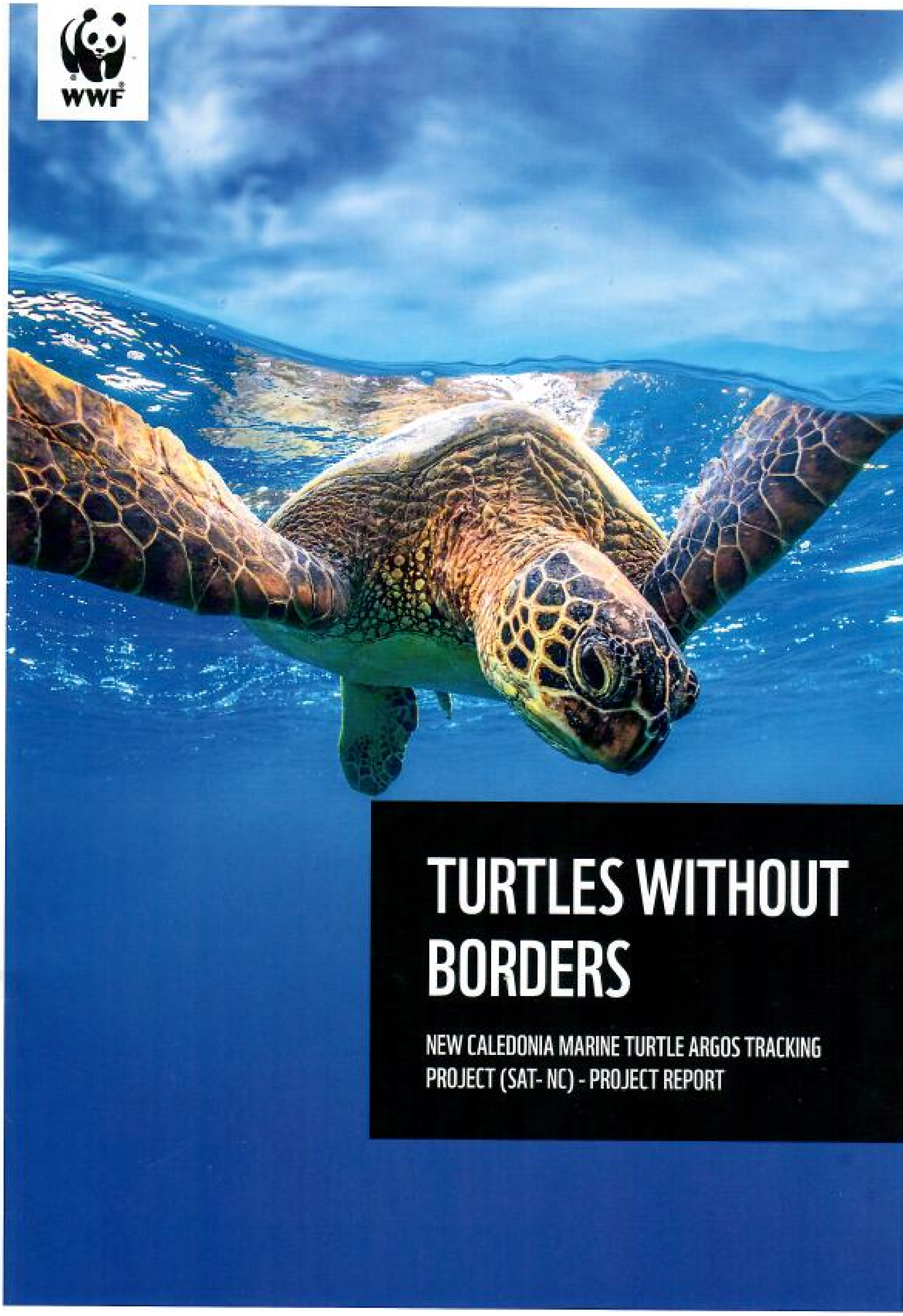

WWF

TURTLES WITHOUT BORDERS

NEW CALEDONIA MARINE TURTLE ARGOS TRACKING PROJECT (SAT- NC) - PROJECT REPORT

WWF

WWF is an independent nature conservation organisation. With over 35 million supporters and an active network in more than 100 countries thanks to its local managers, WWF strives to stop the degradation of the planet's natural environment and build a future where humans live in harmony with nature, by conserving global biological diversity, ensuring sustainable use of renewable natural resources and promoting the reduction of pollution and waste. Since 1973, WWF France has been working on a daily basis to give our future generations a living planet. With its volunteers and the support of its 201,000 sponsors, WWF France leads constructive actions to safeguard natural environments and their species, encourage sustainable lifestyles, train decision makers, assist companies in reducing their ecological footprint and educate young people. However, for change to be acceptable, it can only be achieved through mutual respect. This is why WWF's philosophy is based on dialogue and action.

Monique Barbut is the President of WWF France and Véronique Andrieux is its CEO.

To find out about our projects, visit: wwf.fr

Acknowledgements

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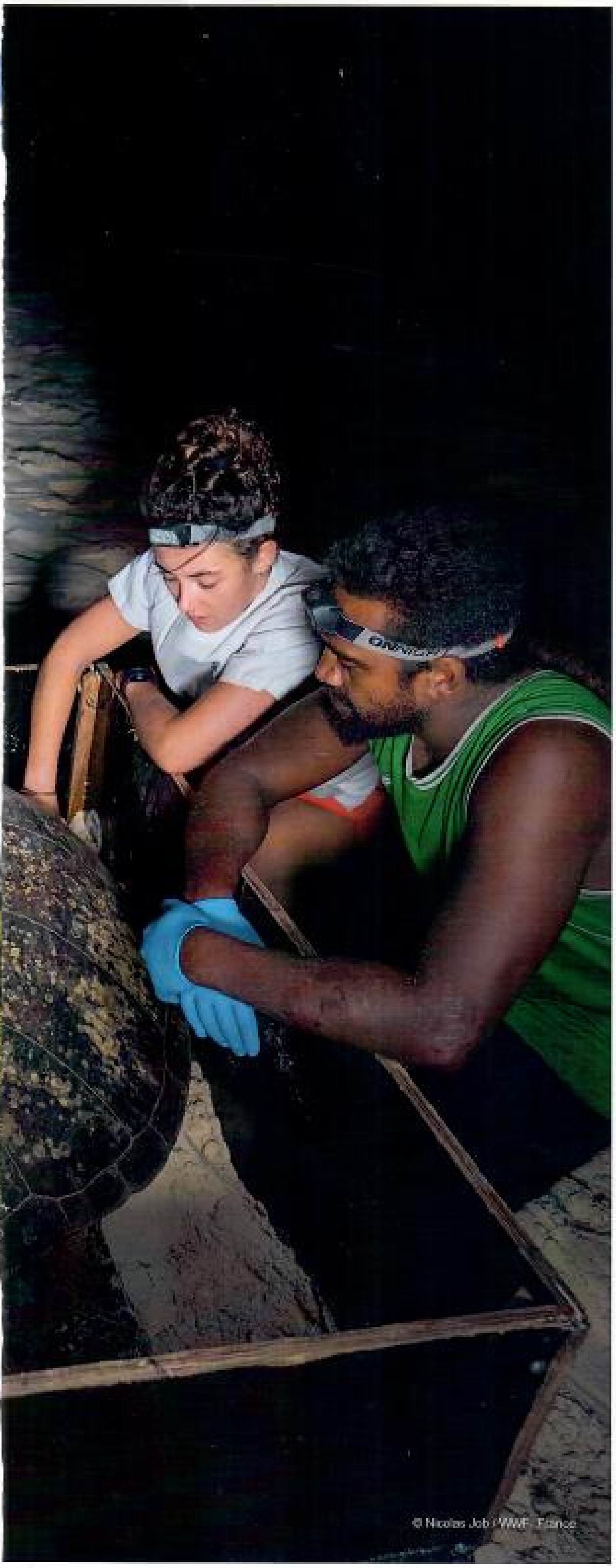
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TABLE OF CONTENTS

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CONTEXT

THE PROTECTION OF MARINE TURTLES - A MAJOR CHALLENGE

Marine turtles are tireless travellers and throughout their life are subjected to multiple threats, the intensity of which depends on the areas that they frequent.

Marine turtles (superfamily Chelonioidea) have existed on earth for over 100 million years. During their evolution, they have experienced and survived important climatic and tectonic changes, as well as the Cretaceous mass extinction that caused the disappearance of dinosaurs. However, despite this resilience and exceptional ability to adapt, marine turtles are currently, more than ever, threatened with extinction.

HUMAN ACTIVITIES ARE CLEARLY THE CAUSE.

Indeed, the first naturalist reports from European seafarers in the 16th Century reported a considerable number of marine turtles observed worldwide (Spotila 2004). At that time, probably hundreds of thousands populated the oceans. Despite obvious protection efforts over the last few decades, we are currently only observing a small proportion of the marine turtle densities that existed prior to anthropogenic impacts.

The critical status of marine turtle populations is now recognised internationally by organisations such as CITES, CMS and UICN . On the national scale, many countries have taken measurement of the threats and have put in place strict regulations and targeted protective measures. However, many populations are continuing to decline at a worrying rate. Even when declines seem contained, populations are struggling to grow, and are much lower than the figures of years gone by.

Marine turtles are difficult to protect due to their very specific life cycle that exposes them to many threats throughout their life (see following section). Their migrations more particularly force them to frequent areas where pressures and regulations are not always the same, especially when they move from one country to another.

1 - Convention on International Trade in Endangered Species of Wild Fauna and Flora.
2 - Convention on the Conservation of Migratory Species of Wild Animals.
3 - International Union for Conservation of Nature.

Thus, effective conservation measures over a given area cannot always guarantee the safeguarding of a species if it finds itself confronted with significant pressures as soon as it leaves a "well-managed" area.

Their protection therefore constitutes a major regional challenge. This challenge is all the more significant when knowledge relating to their movements is incomplete, which is very often the case. Indeed, without establishing firm links, it is very difficult to mobilise managers on a regional scale to ensure a continuity of protection compatible with how these species live.

Based on this observation, thanks to an ambitious deployment of satellite tags, WWF France has developed a unique project that aims to identify all of the main migratory routes of Caledonian marine turtles (i.e. those that are born and breed on the territory).

LIFE CYCLE

A LIFE CONDUCIVE TO HAZARDS

The life of marine turtles is marked by perious travels at every stage of development. Life becomes a real obstacle course punctuated by many threats to be avoided.

Juvenile turtles, barely pulled out of the sand of the beach where they were born, reach the sea and embark on a long journey lasting several years in the deep waters of the open sea; a phase poetically known as the "lost years" referring to the lack of relative knowledge about the life of juvenile turtles during this period (Fig. 1).

At around 5 to 20 years old, they change their diet and reach shallow waters, often along coastal areas (with the exception of leatherback turtles that remain pelagic). They will gradually settle in an area that will become their feeding ground, which they will remain loyal to throughout their entire adult life (Fig. 1).

When they reach sexual maturity, male and female turtles then start to migrate, returning to the area where they were born in order to breed there (Fig. 1). During this period, females will even have to go back on land to lay their eggs. Throughout their life, they will migrate several times back and forth between their feeding ground and breeding ground.

This life cycle will result in a turtle travelling tens of thousands of kilometres throughout its existence. It will therefore be exposed to very different ecosystems, which, depending on the areas, will be caracterized by the existence of different threats and regulations.

THE MAIN THREATS

Fisheries bycatch - Every year, hundreds of thousands of marine turtles die accidentally in nets, victims of industrial fishing. This is the main threat for juvenile turtles that spend the first years of their life in the open sea, but also for adult turtles when they migrate between their nesting and feeding sites.

Habitat loss - Feeding grounds and nesting sites are regularly degraded or even destroyed by man. They are particularly affected by industrial pollution, coastal development, tourism (e.g. disturbance of spawning sites, anchoring of boats), light pollution and uncontrolled pets (dogs, cats)..

Climate change - Climate change has a significant impact on the ecosystems where turtles feed and accentuates the effect of erosion on nesting beaches. It also disturbs the male/female balance of turtles, whose sex is determined by the temperature of nests. Already, as a result of global warming, some sites are producing almost exclusively females (Jensen et al. 2018).

Hunting and poaching - Hunting adults and removing eggs for human consumption remain key causes of the drastic decline in marine turtle populations worldwide. In the Pacific, this hunting has a strong cultural background that needs to be taken into account while making sure that it remains compatible with population renewal. Although turtles are now protected in most countries, poaching persists at levels that often are too high to be sustainable (Pilcher 2021).

Plastic pollution - Marine turtles may mistake plastic floating objects for food and die of suffocation by trying to swallow them. Bycatch items (ghost nets) that trap them may drown a turtle or prevent it from feeding or swimming. Finally, debris on beaches constitutes traps for small turtles and prevents them from reaching the sea.

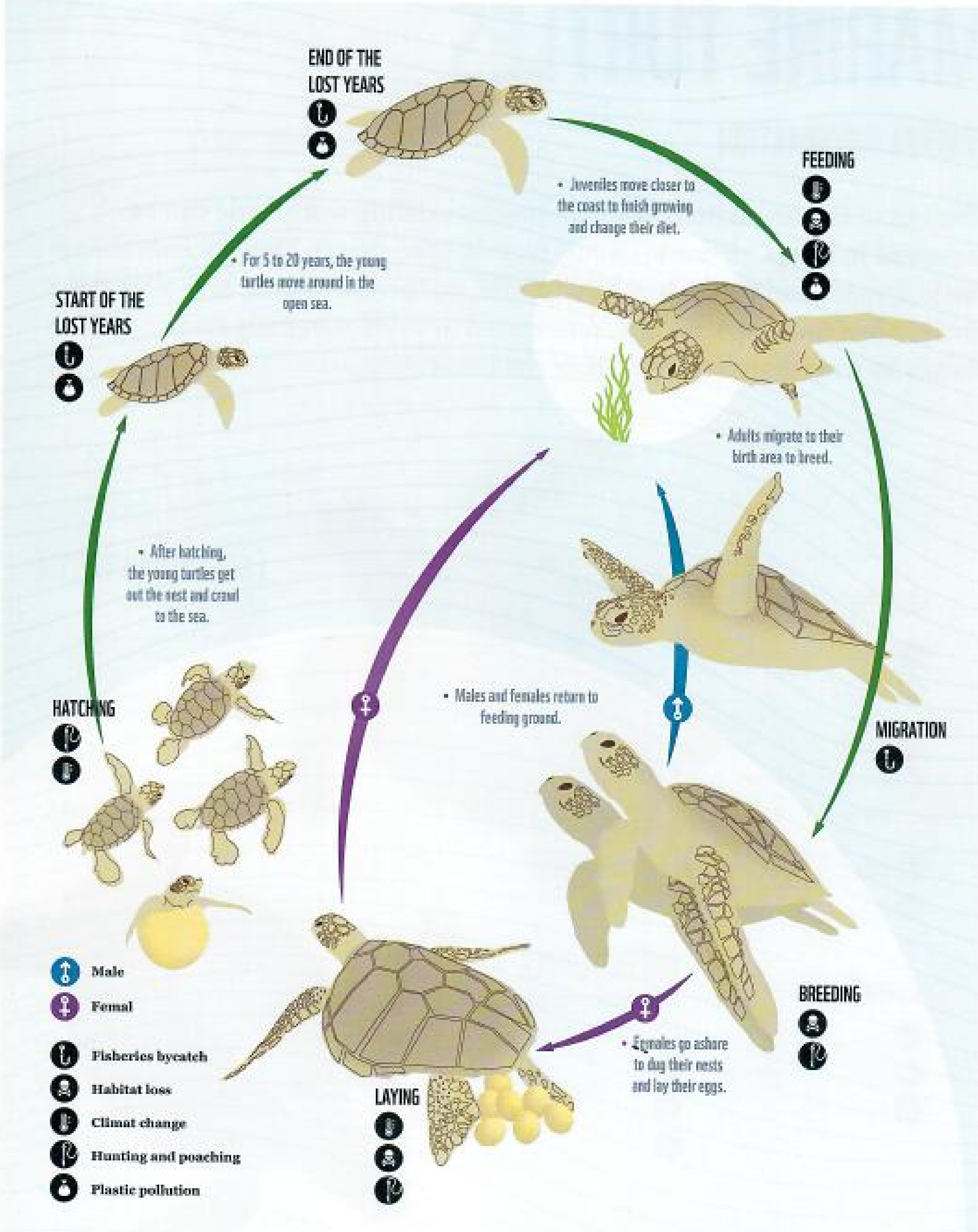


Figure 1: Life cycle of marine turtles and the threats they face.

NEW CALEDONIA MARINE TURTLES

GENERAL INFORMATION

Five out of the seven marine turtle species existing worldwide can be observed in New Caledonia (Etaix-Bonnin et al. 2011). They include the green turtle, loggerhead turtle, hawksbill turtle, leatherback turtle and olive ridley turtle. All of these species are endangered or even extremely endangered as shown by their status on the UICN red list (Fig. 2).

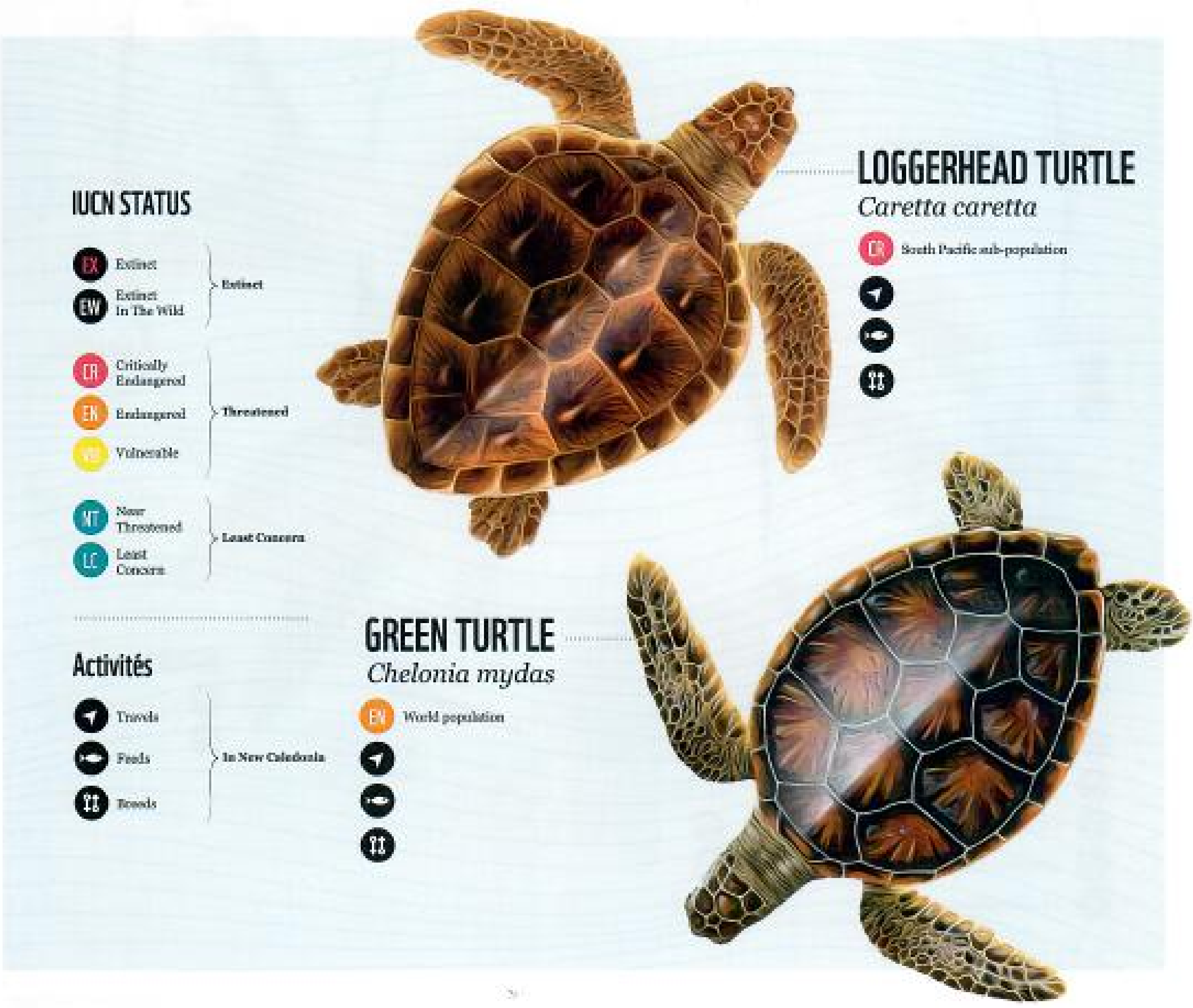


Figure 2: The different species of marine turtles found in New Caledonian waters.

All of them, apart from the olive ridley turtle (which only transits through our waters), feed in New Caledonia, with the specific feature for the leatherback turtle of feeding in the open sea. Green, loggerhead and hawksbill turtles, that are more commonly observed locally, feed exclusively in the shallow waters of coastal and/or lagoon areas.

For these three species, New Caledonia represents an important feeding ground notably thanks to the huge lagoon areas located there.

However, no real information exists on the abundance of these populations.

By feeding here, they spend most of their adult life in New Caledonia but, on the other hand, they do not necessarily originate from this territory.

This is the case, in particular, for hawksbill turtles that do not breed in New Caledonia, and therefore come from other countries such as Vanuatu, the Solomon Islands or Australia. The case of green and loggerhead turtles is different because these two species also breed in several locations throughout the territory (Fig. 3).

Thus, three possible scenarios may concern them :

Those that feed in New Caledonia but originate from another country and return there to breed every 2 to 4 years on average.

Those that are born and breed in New Caledonia but that have their feeding site in another country where they spend most of their life.

Those that are born, breed and feed in New Caledonia and that therefore spend all of their adult life (while probably having left New Caledonia's boundaries during their "lost years").

NESTING SITES

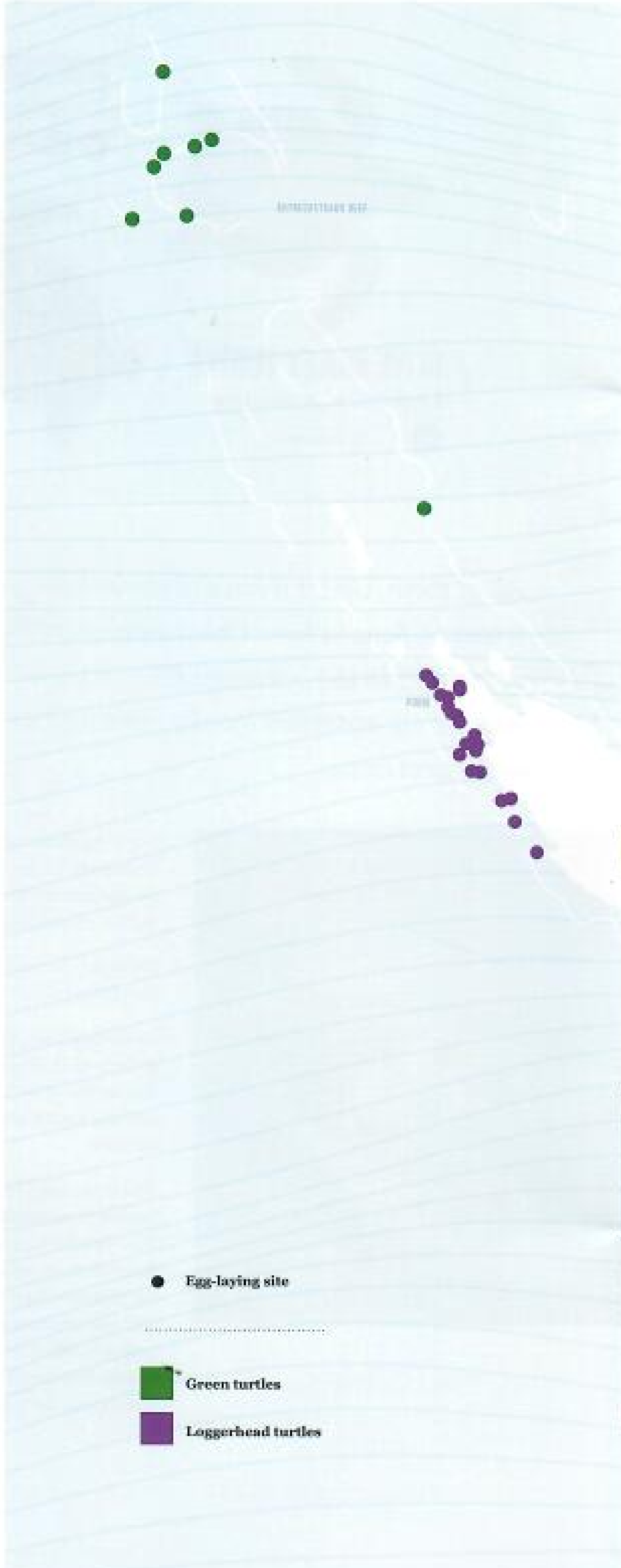
New Caledonia is rich in important and numerous nesting sites for green turtles and loggerhead turtles (Fig. 3). They are distributed over the entire territory with a noticeable difference in the distribution between the two species.

Green turtles

their nesting beaches are present over the entire institutional geography of New Caledonia, namely in the 3 provinces as well as in the Natural Park of the Coral Sea under the responsibility of the New Caledonia Government. Approximately 30 beaches have been listed throughout the entire territory (Fig. 3). Two areas are particularly important for the reproduction of green turtles. They are the Entrecasteaux islands and the Chesterfield islands located in the Natural Park of the Coral Sea (Fretey et al. in press). An exceptional number of nests (between 10,000 and 100,000) are dugged in these two areas every year, making these sites major breeding grounds for green turtles on the global scale. A third area of interest, although to a lesser extent in relation to the first two, is located on the Loyalty Islands on the islands of Ouvéa and Beautemps-Beaupré.

Loggerhead turtles

Their nesting sites are concentrated on the Grande Terre and particularly on the coral islands that are scattered over its huge lagoon. Approximately 50 beaches have been listed throughout the entire territory (Fig. 3). Loggerhead turtles are much less abundant than green turtles with a few hundreds nest dugged every year. However, New Caledonia is an area that is crucial for the critically endangered South Pacific population because it represents at least 30% of the region's nesting sites (the remainder being concentrated on the East Coast of Australia) (Bourgogne pers. comm.). La Roche Percée beach, located on the West coast of the Grande Terre, is the most frequented of the territory in terms of number of nests counted every year (approximately 250 nests/year over the last 10 years, Barbier et al. 2023). Two other areas that have very different configurations are key for the reproduction of the species. These are the islets of Grand Lagon Sud in the South Province and the islets of the Koumac-Poum area in the North Province. These areas are caracterized by a multitude of small coral beaches individually hosting few nests but globally representing a very significant share of the eggs laid in the territory (Mounier 2007, Oremus & Mattei 2017).



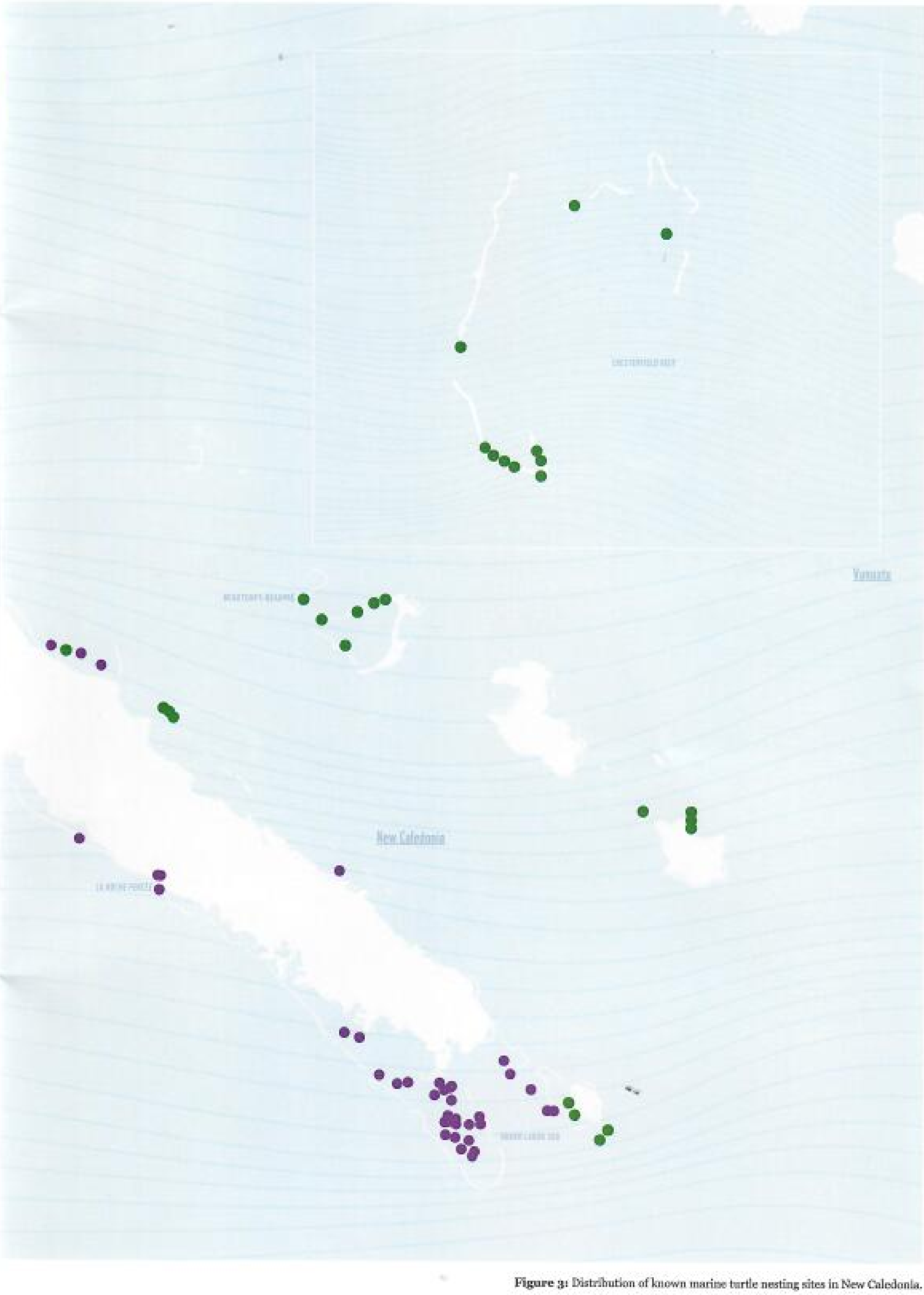


Figure 3: Distribution of known marine turtle nesting sites in New Caledonia.

OBJECTIVES OF THE PROJECT

In order to be effective, marine turtle protection must be addressed on a regional scale, taking into account all the players involved in managing threatened populations. In a context where these co-responsibilities remain poorly documented, establishing and characterising links that connect these managers appears to be a key lever for adopting and implementing an effective and global conservation strategy.

WWF developed the SAT-NC project with the primary aim of identifying the main migratory routes used by Caledonian marine turtles (green and loggerhead) and thereby, the main co-managers involved in the conservation of these populations.

The answer this objective, the following three operational indicators were established:

1 - Deploying 80 satellite tags on Caledonian turtles distributed over the territory's six main nesting sites.

2 - Mapping and characterising the main migratory routes and feeding grounds used by Caledonian turtles.

3 - Identifying the main regional managers having responsibility over the conservation of Caledonian turtles and informing them of these results.

The ultimate aim of the SAT-NC project is to provide and disseminate knowledge that will make it possible to implement and/or increase targeted protective measures by defining firm links and existing responsibilities between the region's managers involved in the conservation of New Caledonia's marine turtles.

WHY USE SATELLITE TRACKING?

CHOOSING THE MOST SUITABLE METHOD

Marine turtles are present over the entire South Pacific and the regional range of their movements is a proven fact. However, characterising the main trends of these movements is more complex.

Significant evidence of connections between the various countries in the region already exist (Pilcher 2021). This evidence is often the result of numbered titanium flipper tags that have been attached to several thousands of turtles during recent decades. The simplicity and low cost of this method have made it a success but the scope of the results acquired generally remains limited when this involves identifying the main migratory routes of a given population of turtles. In fact, to quantify the relative importance of the connections, we need to deploy a substantial recapture effort on all possible feeding grounds, which logistically would be extremely difficult.

Genetics may also provide information on the links that connect certain territories. Mixed-stock analysis methods may thus make it possible to estimate the origin of the turtles that are present on a feeding site by comparing their genetic profile to that from various possible nesting sites (Dethmers et al. 2010). Although powerful, these methods also require significant sampling both on the nesting sites and on all feeding sites. Over the last few decades, many satellite telemetry programmes have been launched, providing much more accurate information on the movements of turtles fitted with these loggers.

In fact, the data collected make it possible to retrace the entire route travelled, particularly between the nesting and feeding areas. Thus, they provide information on behaviours at sea and not merely about a point of departure and arrival.

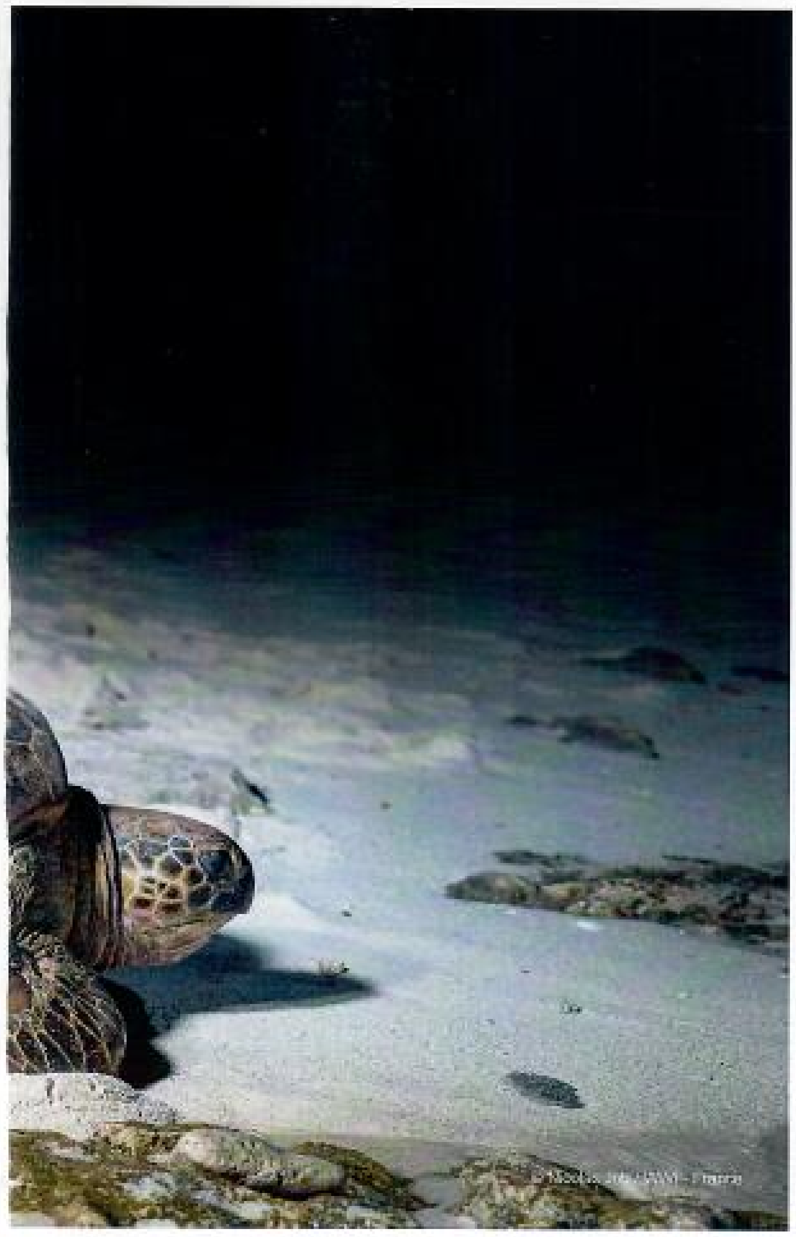
One of the key advantages of satellite tagging lies in the fact that the action on the ground only focuses on deployment of the equipment.

Therefore, thanks to the transmission of data by satellite, there is no need to go to the potential arrival sites. On the other hand, the high costs related to this equipment mean that the number of turtles studied is limited in relation to that of flipper tagged turtles. Most satellite tagging programmes track between 1 and 20 turtles (Jeffer & Godley 2016). Although a limited number of tags may be sufficient to obtain invaluable information, this type of methodology like others encounters the problem of whether the sample size is sufficient to answer the questions raised. For this, there is no magic number.

However, in the case of a project such as SAT-NC, which aims to establish robust migratory trends for the whole of New Caledonia, it is clear that a substantial number of satellite tags are necessary in order to cover the two species concerned and all of the main nesting grounds identified. This is the direction chosen by WWF in setting an ambitious deployment objective on the territorial scale thanks to the support of many institutional and associative partners.

DEPLOYING A SATELLITE TAG

To limit disturbance, while making sure that the equipment is suitably attached, a precise protocol needs to be followed when affixing a satellite tag. The transmitters are designed such that they do not cause any physical or behavioural impact on the animal.



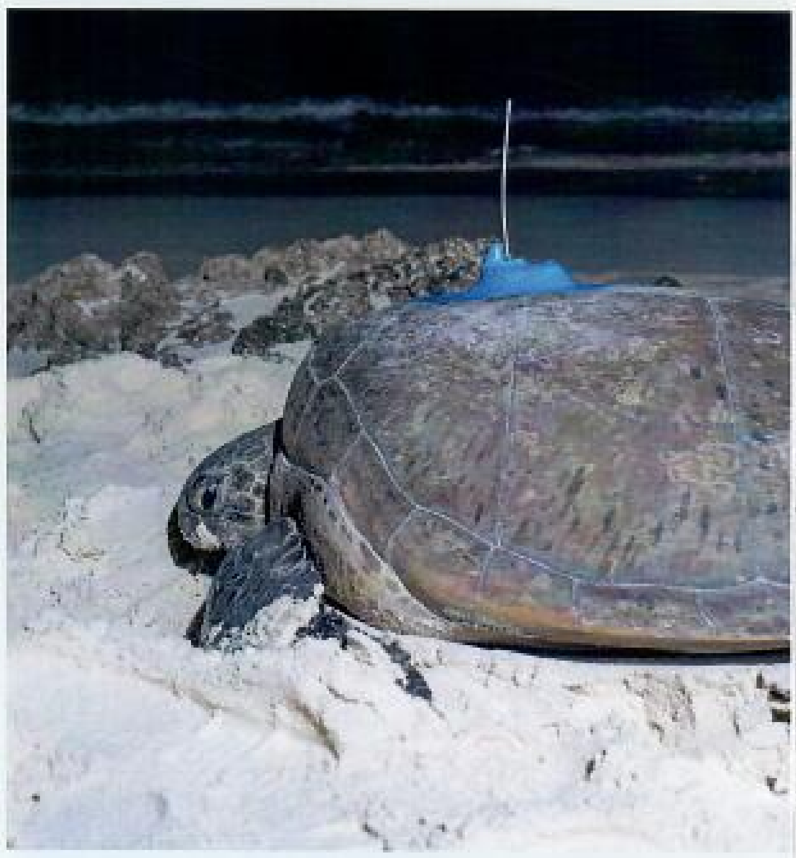
Within the scope of the SAT-NC project, SPOT352/375 (®Wildlife Computers) tags have been deployed on adult females in breeding grounds. When turtles come on to the beaches during nesting, we take the opportunity to tag them before they return to the sea.

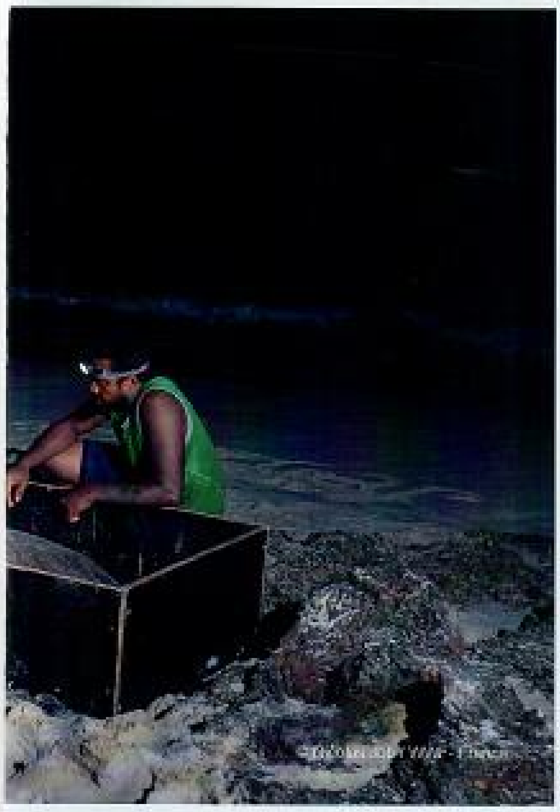
For this, we need to go to the nesting sites during the breeding period. In New Caledonia, this period is from the end of November to the beginning of March, with an egg-laying peak between December and January.

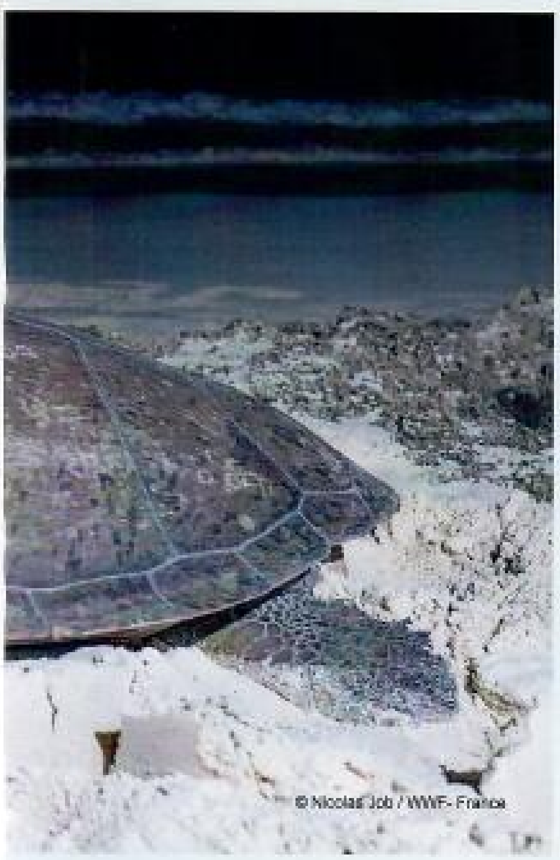
As egg laying mostly takes place at night, rounds are carried out after sunset to attempt to identify a female coming out of the water. No intervention and no disturbance takes place before the turtle starts its descent back towards the sea. Generally, this occurs after the eggs have been laid and the nest has been refilled. Waiting can sometimes last several hours if the turtle encounters difficulties in finding a suitable place for its nest or in digging it. Sometimes, the turtle may decide not to lay eggs. Its time on land will then depend on whether or not it attempts to initiate a nest.

TAG DEPLOYMENT STEPS

When the turtle starts its descent towards the sea, the tagging team intervene to stop it by installing a wooden frame around it. This technique helps to control the animal better by limiting direct contacts and helps to calm it more easily during the tagging time. A towel is also placed over its eyes to limit any stress caused by the movements of people and by the lighting needed to handle the equipment. Once in place, the tag affixing process starts. It follows several precise steps:







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• Firstly, the scute that will receive the tag is cleaned with fine sandpaper and a cloth soaked in acetone. This step, which causes no pain or impact to the turtle, is essential to ensure optimum adherence of the adhesive. The tag is placed on the 2nd vertebral scute starting from the head, enabling it to be ideally placed to facilitate the transmission of data to the satellites when the turtle surfaces to breathe. Indeed, the tag can only communicate with the satellites when its antenna is in air.

• A fibreglass rectangle the size of the scute is then affixed with an epoxy glue to provide an inert and clean base for affixing the tag.

• The latter is then affixed using a malleable epoxy paste that optimises the hydrodynamism of the whole and therefore reduces friction.

• In order to reinforce the overall strength, fibreglass strips placed straddling the tag and the carapace are affixed using liquid epoxy on the front, rear and sides of the equipment.

• A final step involves painting the tag and fibreglass base with an "anti-fouling" paint that will prevent algae and other living organisms from attaching that may disturb the mobility of the turtle and the operation of the equipment.

• When the anti-fouling is dry, the turtle is immediately released from the frame and returns by itself to the sea. On average, the turtle is kept within the frame for 45 minutes so that all of the steps can be performed with sufficient drying of the adhesives.

At the same time as the tagging process, the team takes advantage of the final drying time to attach a flipper tag that will make it possible to re-identify the turtle at a later date when the tag will have fallen. A small 2 mm3 skin sample is also taken to be able to document the genetic profile of the animal.

TAGGING EFFORT: WHERE, HOW MANY AND WITH WHOM?

New Caledonia is a territory with an abundance of green and loggerhead turtle nesting sites, which are of major importance at the South Pacific scale. Documenting the migratory routes in all of these areas constitutes a real logistical challenge requiring suitable sampling and the support of many partners.

TAGGING AREAS

In order to achieve SAT-NC project's objective and provide global insight into the migratory routes of all Caledonian turtles, it was essential to consider all of the main nesting grounds known for both green turtles and loggerhead turtles. Indeed, although all located within New Caledonia, they are likely to represent independent populations, even within the same species, and therefore to be characterised by different migratory routes. In particular, it is documented that Chesterfield and Entrecasteaux green turtles are genetically different from one another

(Read et al. 2015). Although the relative importance of all of the nesting grounds is not specifically known, the available knowledge makes it possible to identify two key areas for each of the two species concerned. For green turtles, this concerns **Entrecasteaux** and **Chesterfield**; for loggerhead turtles, this concerns **La Roche Percée** and **Grand Lagon Sud** (Fig.3).

These four areas have been the focus of particular attention with a higher target of number of satellite tags deployed.

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Thus, the target was set at 20 tags each for Entrecasteaux, Chesterfield and La Roche Percée. This was reduced to 10 tags for Grand Lagon Sud in anticipation of the increased difficulty in finding nesting turtles in this specific area. Two additional areas considered important as well, but less frequented than the previous 4 areas, were also included with a reduced target of 5 tags each. These are the nesting areas of the **Ouvéa/Beautemps-Beaupré** (green turtles) and **Poum-Koumac** islands (loggerhead turtles) (Fig. 3). The aim of including these secondary areas is to adopt the most comprehensive approach possible when characterising migratory routes despite the difficulties caused by the multiplication of tagging areas. The SAT-NC project's sampling effort has therefore been established over a total of **80 tags deployed on 6 different nesting sites.**

A HIGHLY COLLABORATIVE "COUNTRY" PROJECT

SAT-NC is one of the rare biodiversity conservation projects involving all the main collectivities of New Caledonia. The nesting sites selected are distributed over the three provinces (South Province, Loyalty Islands Province, North Province) as well as over the Natural Park of the Coral Sea, managed by the New Caledonia Government. In addition to the authorisations issued to affix tags in each of their areas of jurisdiction, all of the collectivities involved have actively contributed to the implementation of the SAT-NC project. This contribution includes:

1) the mobilisation of governmental and provincial technical officers in each of the six nesting grounds, who have actively participated in the land operation and notably in affixing tags;

2) logistical support with notably the provision of nautical resources;

3) building contacts with local NGOs and customary authorities involved in the project;

4) sharing their knowledge and experience in the field to facilitate the project's implementation.

The contribution of the local collectivities was essential and the project would not have been possible without it. The SAT-NC project has also been able to rely on the precious help of local associations for the protection of the environment in the areas where they are present. WWF has been able to work with Bwärä Tortues Marines (La Roche Percée site), Association de Sauvegarde de la Biodiversité d'Ouvéa (Beautemps-Beaupré site), Nixumwaak Environnement (Northwest Lagoon, Koumac sites), and Hülili Malep (Northwest Lagoon, Poum sites). These associations were trained by WWF in affixing satellite tags, which they have themselves subsequently been able to deploy on certain turtles. What is more, the expertise in the field and logistical support of these associations have significantly contributed to the SAT-NC project's success in their respective areas.

Lastly, the Aquarium des Lagons de Nouvelle-Calédonie is directly involved in the SAT-NC project and its promotion with the general public. One of the Aquarium's major contributions concerns the provision of results obtained on previous satellite tagging campaigns carried out on the La Roche Percée (3 tags) and Entrecasteaux (3 tags) sites. These results are given a second life here and help to significantly expand the project's overall database.

RESULTS

TAGGING SUCCESS

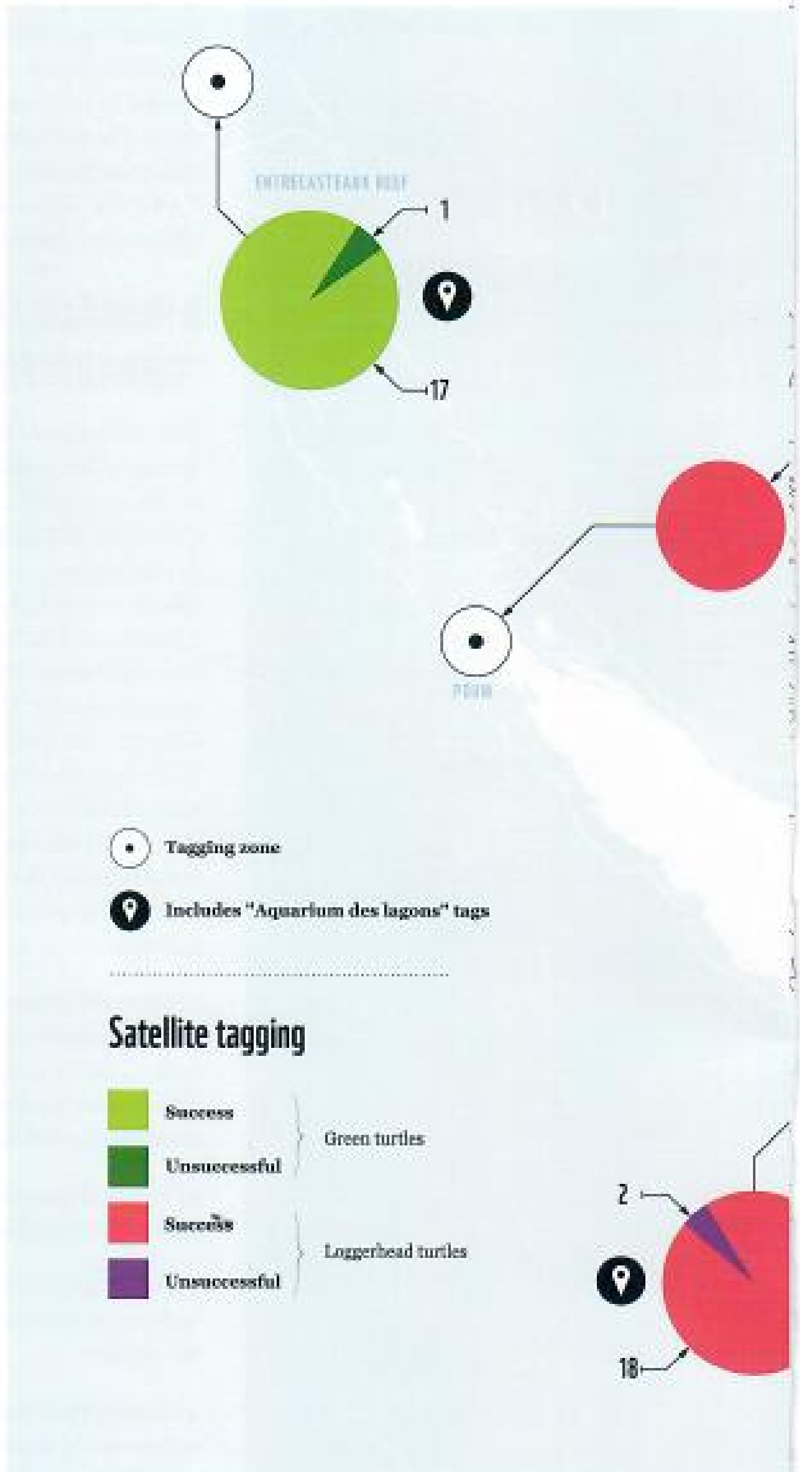
Out of 86 tags deployed, a total of 79 complete migrations were obtained!

Between 2016 and January 2023, WWF and its partners deployed 80 Argos tags on the main marine turtle nesting sites in New Caledonia.

The initial objective set has therefore been achieved. 73 out of the WWF's 80 tags have made it possible to obtain the recording of a complete migration between the nesting site and the feeding ground, giving a success rate of 91%. With the addition of the 6 Aquarium des Lagons tags, the overall database represents a total of 79 complete migrations.

The initial sampling plan has been slightly modified throughout the project in order to adapt to certain difficulties in the field but also to step up the number of deployments in particular areas of interest.

On the whole, the distribution of the number of tags for each species has, however, been respected with 47 tags deployed on green turtles and 33 deployed on loggerhead turtles.



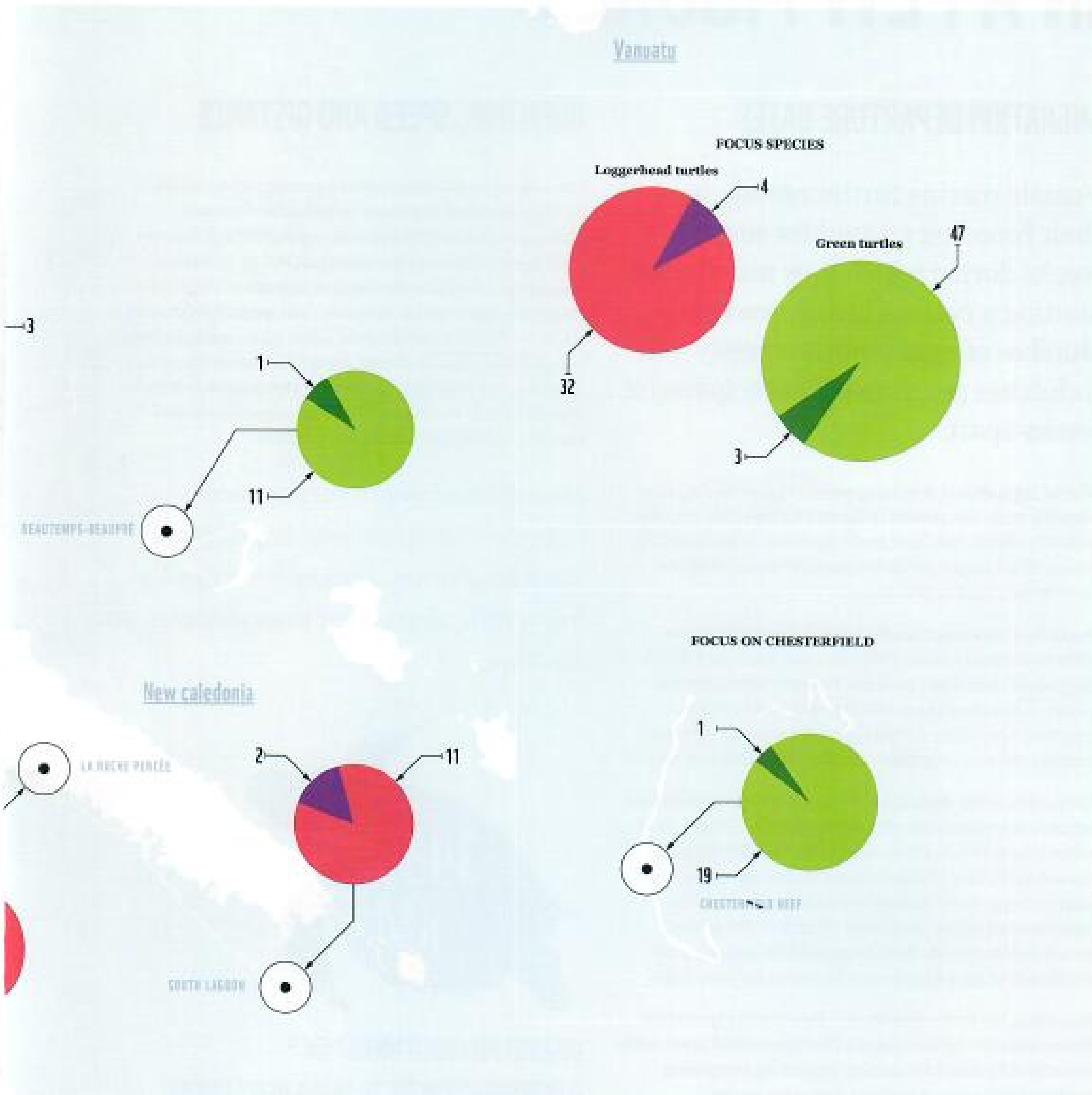


Figure 4: SAT-NC study sites and tagging effort.

MIGRATION CHARACTERISTICS IN A FEW FIGURES

MIGRATION DEPARTURE DATES

Female marine turtles remain in their breeding ground for several weeks during which they mate before starting a cycle of laying several clutches of eggs (approximately 3 to 5 clutches per season), each spaced 2 weeks apart.

When a tag is affixed, it is not possible to know the date from when the turtle was present in the nesting area. Nevertheless, SAT-NC project's data have made it possible to determine the date on which tagged turtles started their return migration towards their feeding ground.

The earliest departure recorded was 26 December (green turtle from Entrecasteaux); the latest observed was 3 March (loggerhead turtle from La Roche Percée). Overall, the two species do not show any noteworthy difference in their departure date, which on average occurs around 1 February. However, there is a significant difference between individuals.

The analysis of the departure dates confirms that tagging does not affect the reproductive behaviour of turtles. In fact, ¾ of turtles remained in the area to lay more eggs after tagging. Those that left shortly after (without further egg laying) were generally tagged later in the season. Lastly, the departure dates observed within the context of the SAT-NC project, are compatible with the knowledge available regarding the distribution of egg laying during the season (or phenology).

On average, the turtles remained in their nesting ground for 28 days after having been tagged. One Chesterfield green turtle even stayed 85 days after tagging, suggesting a surprising number of 7 clutches of eggs laid during the season.

DURATION, SPEED AND DISTANCE

The migration of marine turtles represents a true journey during which they may cover considerable distances. However, what does that actually correspond to? Here are a few figures to answer this question (Fig. 5). In terms of distance and duration, the range of migrations observed is enormous. Some turtles complete short migrations in just a few days. The shortest observed is less than 100km and was completed in 1 day. However, many others cover more than 1,000km, reaching their destination after a journey of more than 2 months. The longest observed migration covered almost 4,000km and lasted over 3 months.

On average, green turtles cover approximately 50 km/day during their migration. Loggerhead turtles are a little slower but even so cover 40 km/day.

LONGEST RECORDED MIGRATION
(LOGGERHEAD TURTLE TO PAPUA NEW GUINEA)

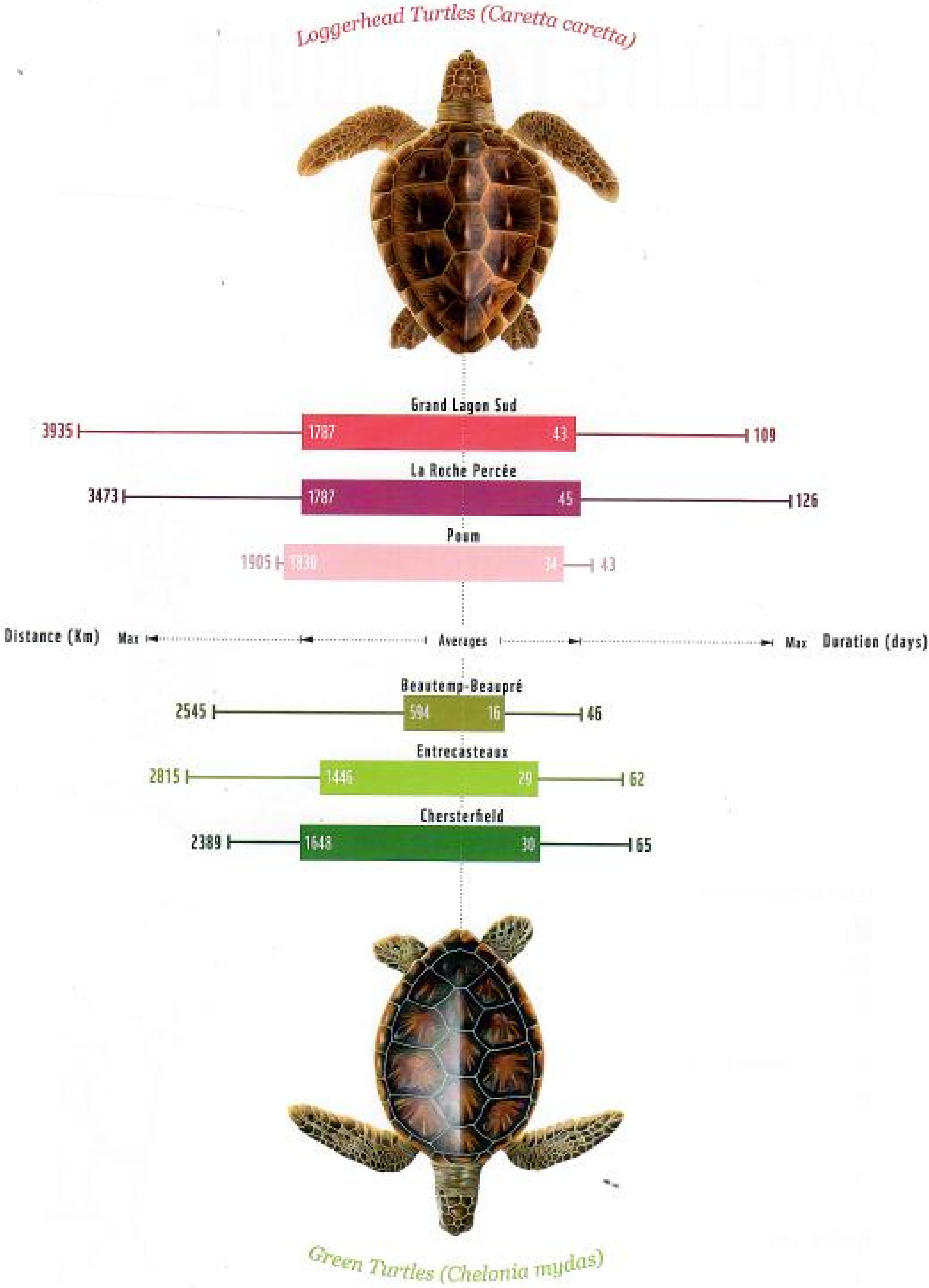
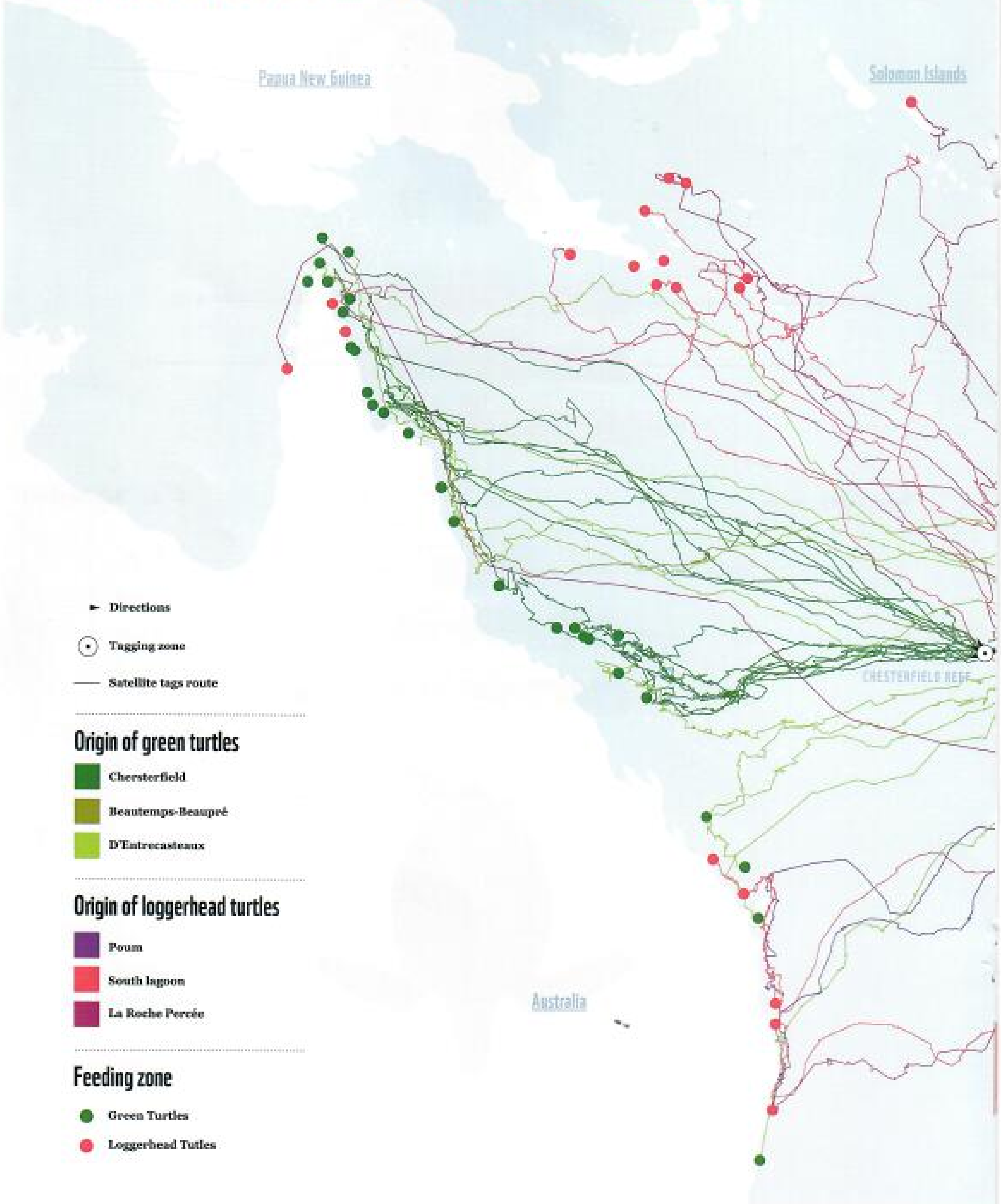


Figure 5: Distances and durations of migrations recorded according to nesting sites.

SATELLITE TAGS ROUTE



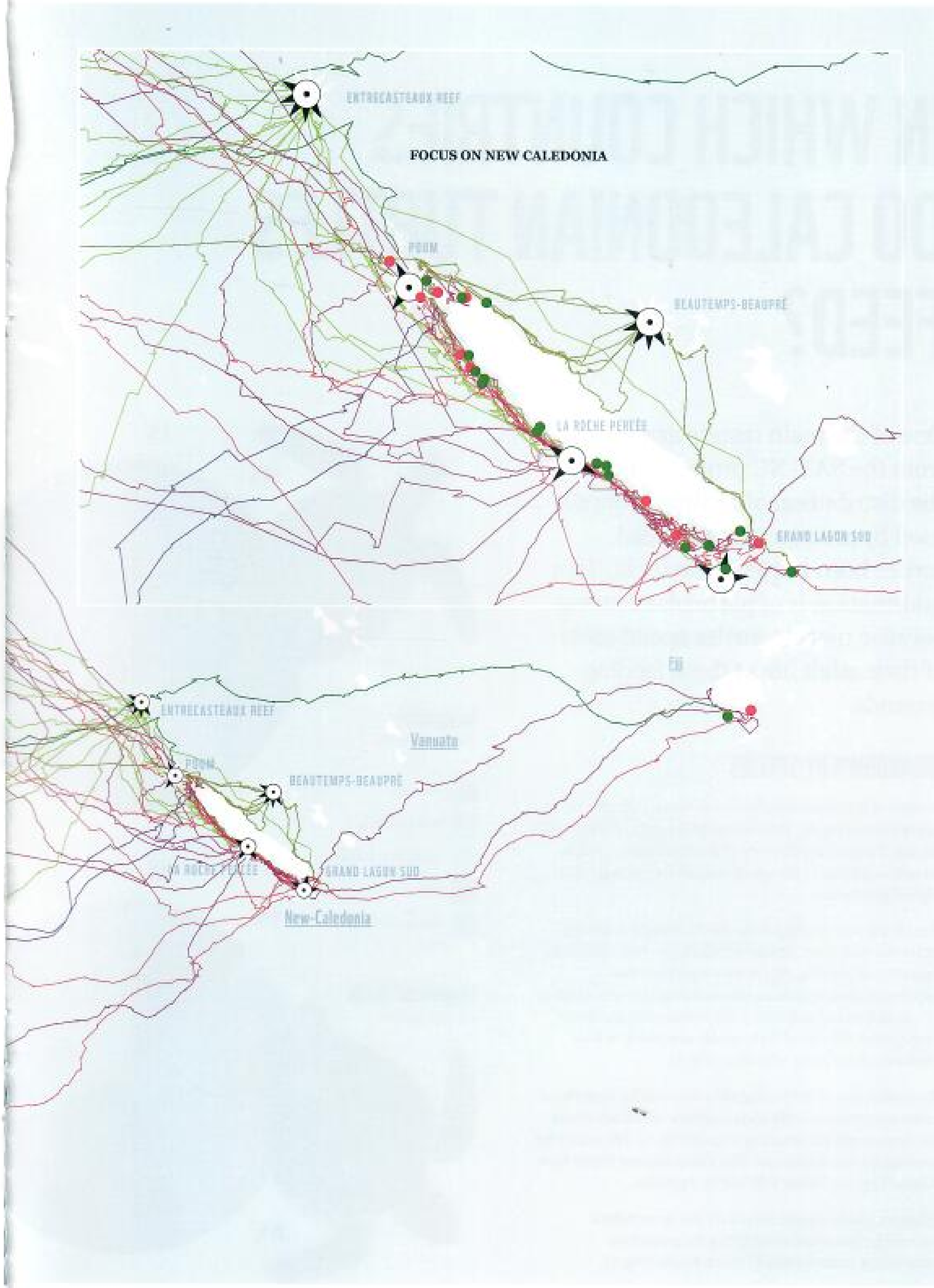
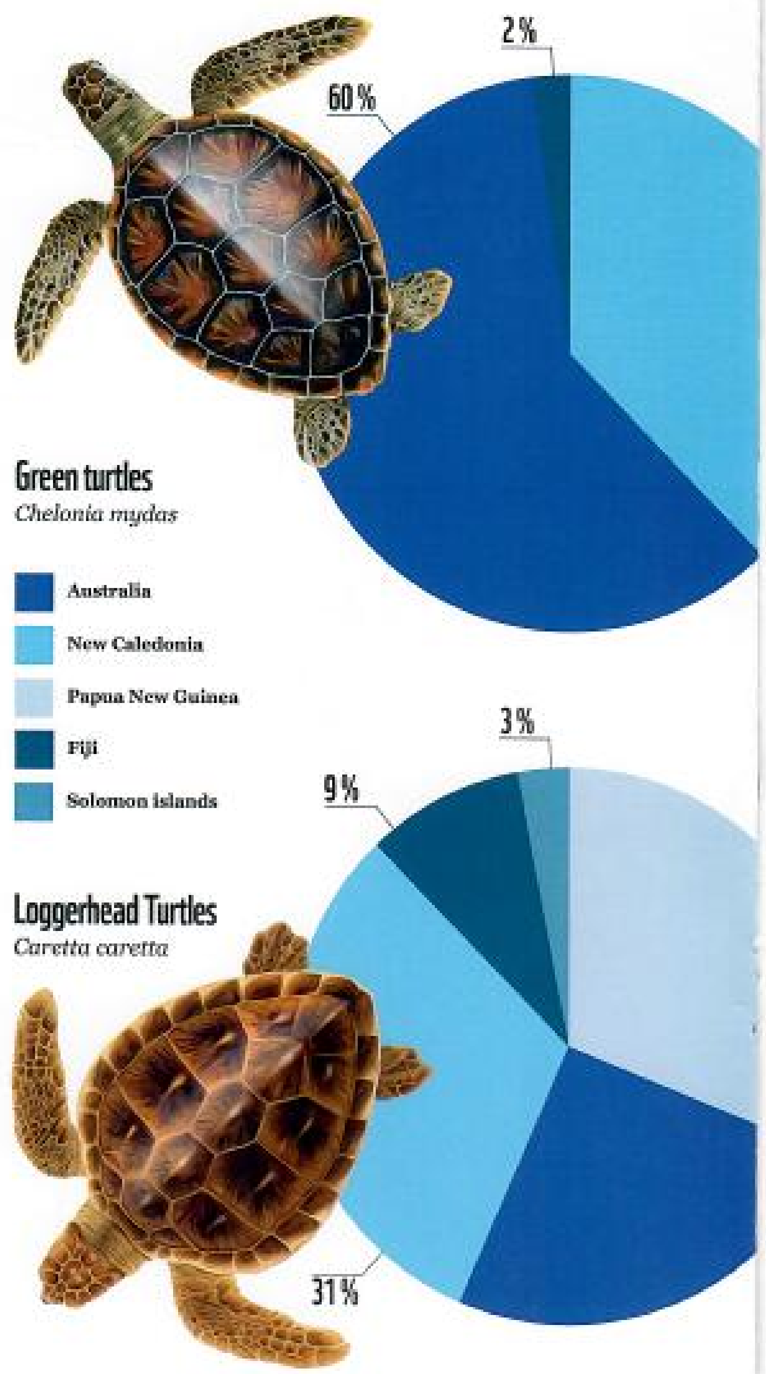


Figure 6: Migration routes and feeding areas recorded by satellite tagging.

IN WHICH COUNTRIES DO CALEDONIAN TURTLES FEED?

One of the main results expected from the SAT-NC project concerns the distribution of feeding grounds used by green and loggerhead turtles born in New Caledonia. This information is of particular interest because marine turtles spend most of their adult life at these feeding grounds.



BREAKDOWN BY SPECIES

We were able to accurately locate the feeding sites for 79 tagged turtles (Fig. 6). The results obtained show clear trends but also illustrate the diversity of the distribution profiles not only according to the species but also according to the original population.

There is a certain overlap in the destinations of 2 species, with 3 identical "host" countries, which are: New Caledonia, Australia and Fiji (Fig. 6). On the other hand, the proportions observed are significantly different with notably a predominance of Australia as the feeding destination for green turtles, the rest of them mostly remaining in New Caledonia after a short migration (Fig. 7).

The distribution of the feeding sites observed for loggerhead turtles concerns two additional countries, which are Papua New Guinea and the Solomon Islands (Fig. 6). The main host countries for this species are New Caledonia and Papua New Guinea. They are closely followed by Australia.

Fiji appears to be a more secondary but nevertheless interesting destination considering the precarious conservation of the species in South Pacific (Fig. 7).

The differences observed between green and loggerhead turtles must nevertheless be interpreted with precaution because the results also show some noteworthy differences within the same species, according to the original nesting ground. From an ecological point of view, it is therefore more relevant to analyse this distribution on the nesting ground scale and all the more so as they have not all benefited from the same sampling effort.

BREAKDOWN BY NESTING GROUND

Green turtles – The distribution of feeding grounds differs significantly between the 3 nesting sites studied here. Yet, the overwhelming majority of feeding grounds for green turtles are concentrated in only two countries: Australia and New Caledonia (Fig. 7). The Chesterfield and Beautemps-Beaupré sites represent two opposites: for Chesterfield, the East Coast of Australia is the preferred destination; for Beautemps-Beaupré, the Grande Terre of New Caledonia is the preferred destination. The Entrecasteaux site presents an intermediate situation with a relatively balanced distribution between the two countries (even so in favour of Australia).

Loggerhead turtles – Conversely, the two main sites studied for loggerhead turtles (La Roche Percée and Grand Lagon Sud) show an extremely similar distribution of host countries and this despite the higher number of destinations (Fig. 7). The distribution of turtles for Lagon Nord-Ouest may appear to be different but it is based on a reduced sample of 3 tagged turtles. A robust comparison is therefore impossible at this stage and a further tagging effort will be required in this area.

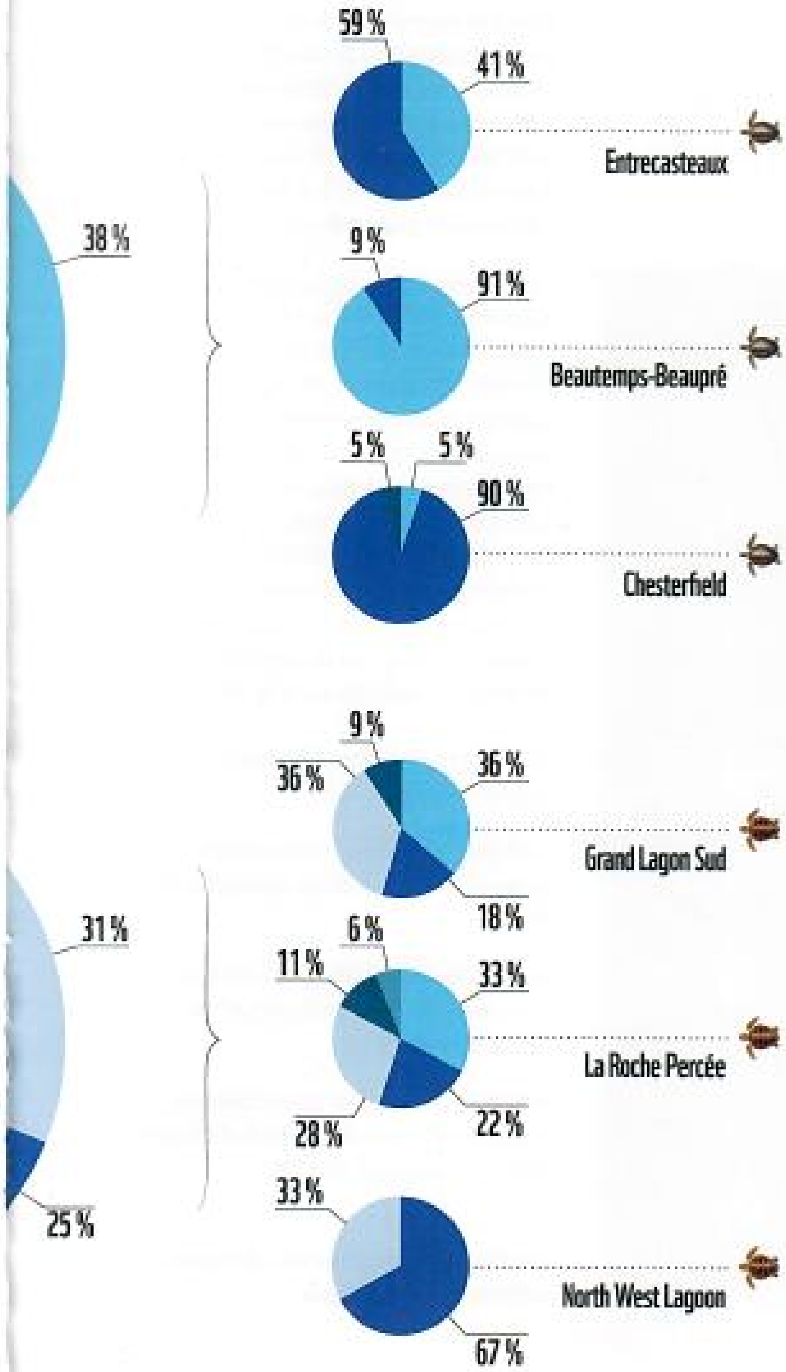
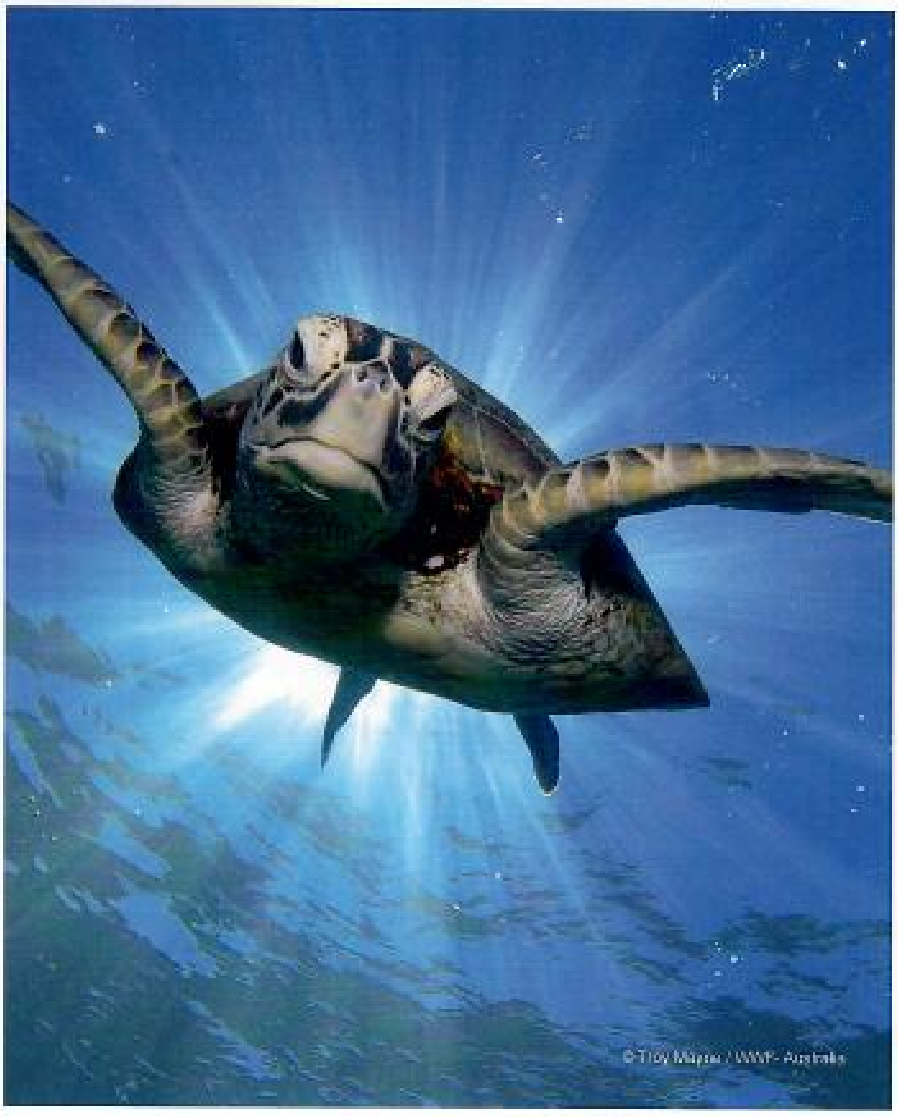


Figure 7: Distribution of countries hosting feeding grounds for marine turtles originating from New Caledonia, by species and nesting area.

CALEDONIAN TURTLE MIGRATORY ROUTES

One of the most enigmatic parts of the life of marine turtles concerns their movements on the high seas. Yet, significant pressures such as fisheries bycatch threaten marine turtles there. Thanks to satellite tagging, the migratory routes can be accurately retraced and thus, priority conservation areas can be identified.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MIGRATORY CORRIDORS

The movements recorded thanks to satellite tags show a wide range of possible migrations, from East to West and from North to South (Fig. 6). However, a trend is clearly observed with long distance migrations (> 1,000 km) mainly heading Westward. Only 4 individuals (one green and three loggerhead) migrated eastward.

In addition to this global trend, the migratory routes of the two species studied here also show high sea areas of particular interest. In fact, the superposition of the routes indicates the existence of certain preferred transit areas according to the final destination of the turtles. Although these areas sometimes cover a width of almost 500 km, the scale of the movements in which they take place means that they can be considered as **migratory corridors** (Fig. 8).

For the green turtles, the main migratory corridors are:

1) **West** (where the turtles head towards the South of the Great Barrier Reef);

2) **North-West** (where the turtles head towards the North part of the Great Barrier Reef):

3) **South** (where the Entrecasteaux turtles head towards the Grande Terre of New Caledonia) (Fig. 8).

For the loggerhead turtles, the main migratory corridors are:

1) **North-West** (where the turtles head towards Papua New Guinea);

2) **South-West** (where they head towards the South of Queensland);

3) **East** (where they head towards Fiji) (Fig. 8).

INFLUENCE OF ENVIRONMENTAL PARAMETERS

The migration phenomenon remains mysterious on many levels but the use of satellite tags may help to answer certain questions, notably regarding how environmental parameters influence the behaviour of turtles.

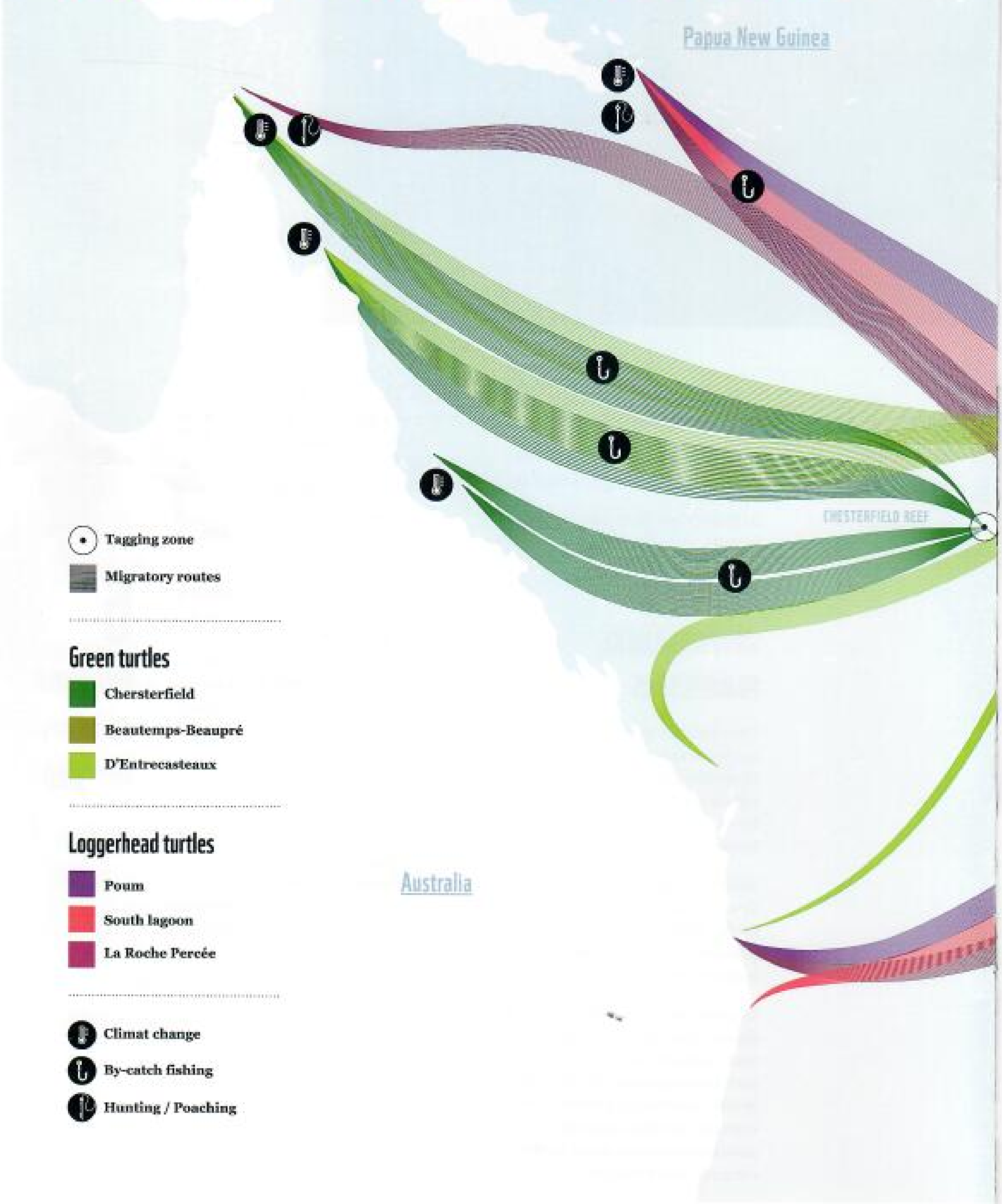
Analysis of the SAT-NC data has therefore given us some useful insights on the effect of currents, bathymetry, primary production or water temperature.

In particular, it was noted that currents do not influence how turtles choose their final destination. As soon as they start their migration they head in a specific direction, regardless of the currents that they encounter. Yet, their movements are influenced by these currents, which may help or hinder them in reaching a destination, and may also deviate the route of the turtle, which sometimes has to correct its direction to reach its destination safe and sound. These deviations probably partly explain why the migratory corridors identified are sometimes extremely wide.

The depth of the water, or bathymetry, plays an important role as soon as it becomes less than 100 m deep. This mainly concerns coastal areas where it is observed that the swimming speed slows and changes in direction become more frequent. These coastal areas probably assist navigation, particularly over the final part of the migration enabling the turtle to reach a specific feeding ground.

The influence of temperature and primary production are not so obvious even though it would appear that green turtles swim a little faster in warm water.

MIGRATORY GLOBAL TREND



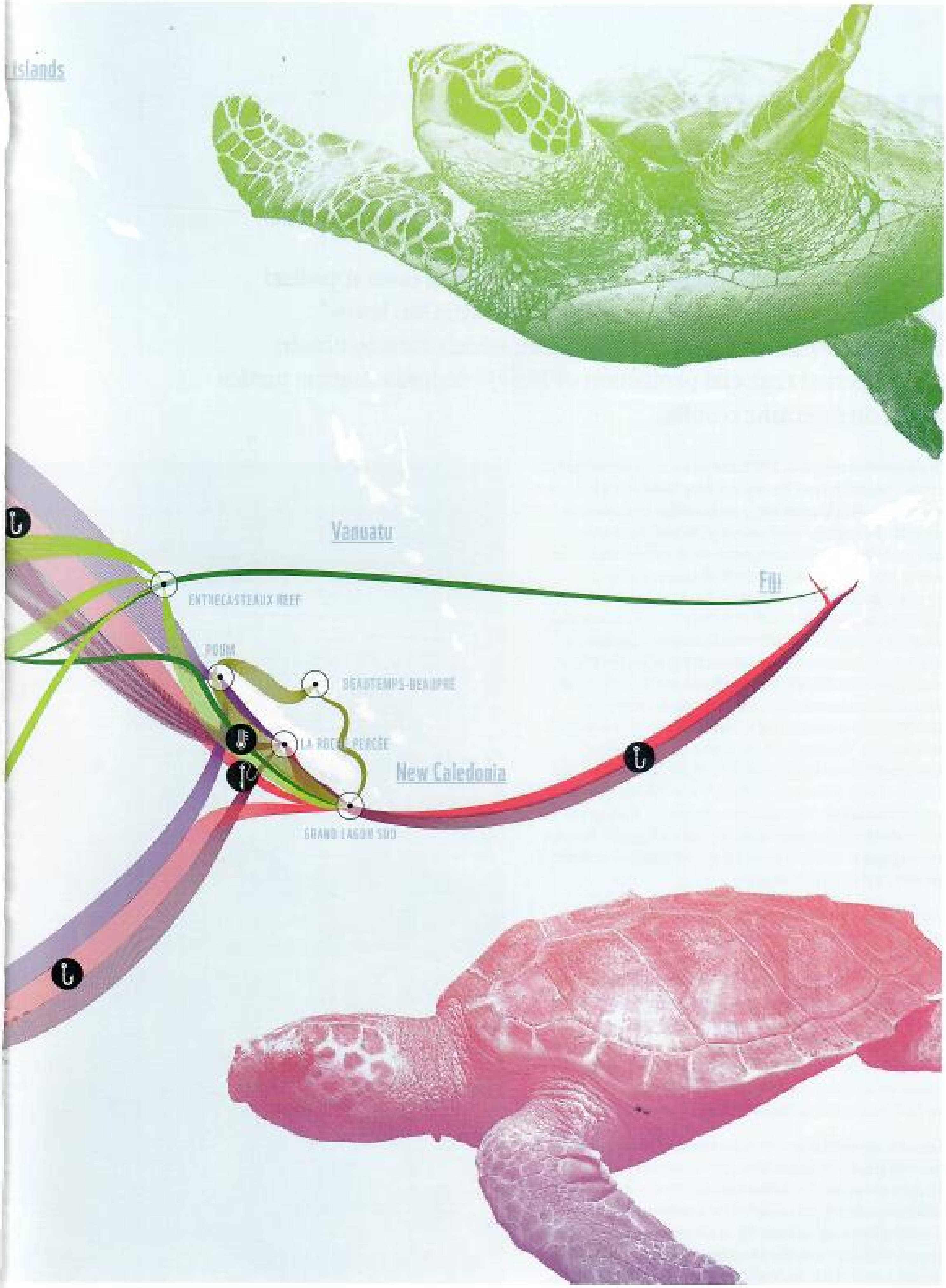


Figure 8: Main migration corridors used by New Caledonian marine turtles and approximate distribution of the main threats.

DISCUSSION

"WE LOVE WHAT AMAZES US, AND WE PROTECT WHAT WE LOVE".

This quote by Jacques-Yves Cousteau has often been repeated and shortened particularly to "we protect what we know". This is the spirit of the SAT-NC project, which aims to obtain strengthened regional protection of New Caledonia marine turtles based on scientific results.

To achieve this objective, WWF and its partners have deployed a major tagging project throughout New Caledonia taking care to integrate all of the territory's main marine turtle nesting grounds. Through the deployment of 86 tags, 79 of which have made it possible to comprehensively record migrations between the nesting site and the feeding ground, this study positions itself on a short-list of studies based on such an important tagging effort (Jeffers & Godley 2016). The primary benefit of this ambitious approach is to make it possible to evaluate proportions of the population travelling to various feeding grounds (Hays & Hawkes 2018) and thus formulate weighted recommendations. Of course, in the context of SAT-NC, several species and populations are considered in the sampling. Therefore, on the whole, the figures obtained should not be over-interpreted. Effectively, these figures are likely to change for certain nesting sites according to new tagging campaigns. That said, the main trends highlighted by this study illustrate a sufficiently reliable ecological reality for drawing robust conclusions and recommendations in terms of conservation on a regional scale.

Our choice for the telemetry approach is based on the geographical context of the South Pacific. Indeed, the presence of a very large number of small insular territories (some twenty or more) distributed over this vast expanse of ocean results in a multitude of possible feeding grounds and migratory corridors for Caledonian marine turtles. Thanks to satellite technology, it is possible to focus the field effort on the point of departure, i.e. New Caledonia, and therefore overcome significant sampling constraints that would involve other methodologies such as flipper tagging or genetics.

Although the main objective of the tagging was to characterise the main migratory routes taken by Caledonian turtles, it can be noted that the data obtained have also provided information on the phenology of the breeding season according to the species and the nesting grounds.
In particular, this concerns the dates when the turtles start to migrate back to their feeding grounds.

This type of knowledge is usually deduced from changes in the nesting activity during the season. However, in some geographical areas, as is notably the case on the Natural Park of the Coral Sea sites, these data are not available. Therefore, in addition to its primary objectives, the SAT-NC project enhances specific knowledge about marine turtle reproduction in New Caledonia. The deployment of satellite tags on marine turtles began several decades ago, making these species the most tracked by means of this technology (Hays & Hawkes 2018). However, it remains without saying that particular care must be taken when using this type of methodology because it involves direct interaction with endangered species.

The development of equipment has paved the way for significant progress in terms of weight, hydrodynamism and attachment system. The tags used in this study represent less than 1% of the average weight of the turtles equipped, far from the recommended limits (5% of the animal's weight). Nevertheless, for this type of study, it is important to continue looking at the potential disturbances caused, particularly due to direct intervention on the animal when affixing tags. We therefore monitored the behaviour of turtles after tagging in order to assess a potential impact on subsequent egg-laying throughout the same season. In this respect, the results showed that tagged turtles continue their breeding season in a normal way.

FEEDING GROUNDS

The differences between species and populations highlighted by the study confirm the importance of the overall approach implemented through SAT-NC. In fact, specific features appear with their own conservation and management implications. The feeding grounds are the first illustration of this.

Green Turtles

The tagging of Caledonian green turtles confirms a trend described previously by means of flipper tagging results (Read et al. 2014), namely that the Australian Great Barrier Reef represents a major feeding ground for our populations (final destination for 55% of the green turtles tagged). Similarly, the link existing between the Entrecasteaux nesting site and the Grande Terre of New Caledonia has also been established by these means. On the other hand, the weighting permitted by satellite tagging, helps us to specify these trends and highlight glaring differences between the 3 main nesting grounds studied here: Chesterfield, Entrecasteaux and Beautemps-Beaupré.

The importance of the Grande Terre as a feeding ground is reinforced particularly for the green turtles from Entrecasteaux (approximately 40% of the turtles tagged) but also and above all for those from Beautemps-Beaupré (approximately 90% of the turtles tagged). These individuals therefore remain within the boundary of New Caledonia during their adult life. However, our resutls show that they travel between different local jurisdictions (Fig. 9).

The link between the Great Barrier Reef is particularly strong for the green turtles from Chesterfield with almost 90% of their feeding grounds concentrated within this geographical area. On the other hand, they seem to be less present in the South of the East Coast of Australia as opposed to the green turtles from Entrecasteaux, a significant proportion of which (more than 20%) go to this feeding ground. Beyond the international distribution, the results offered by satellite tagging also highlight particular areas of interest for feeding.

This is the case on the Great Barrier Reef with an uneven distribution of feeding sites notably suggesting the importance of the North-East of the Cape York Peninsula. This is also the case for the Grande Terre with a distribution of feeding grounds clearly biased on the West coast of the Island (Fig. 6).

Loggerhead Turtles

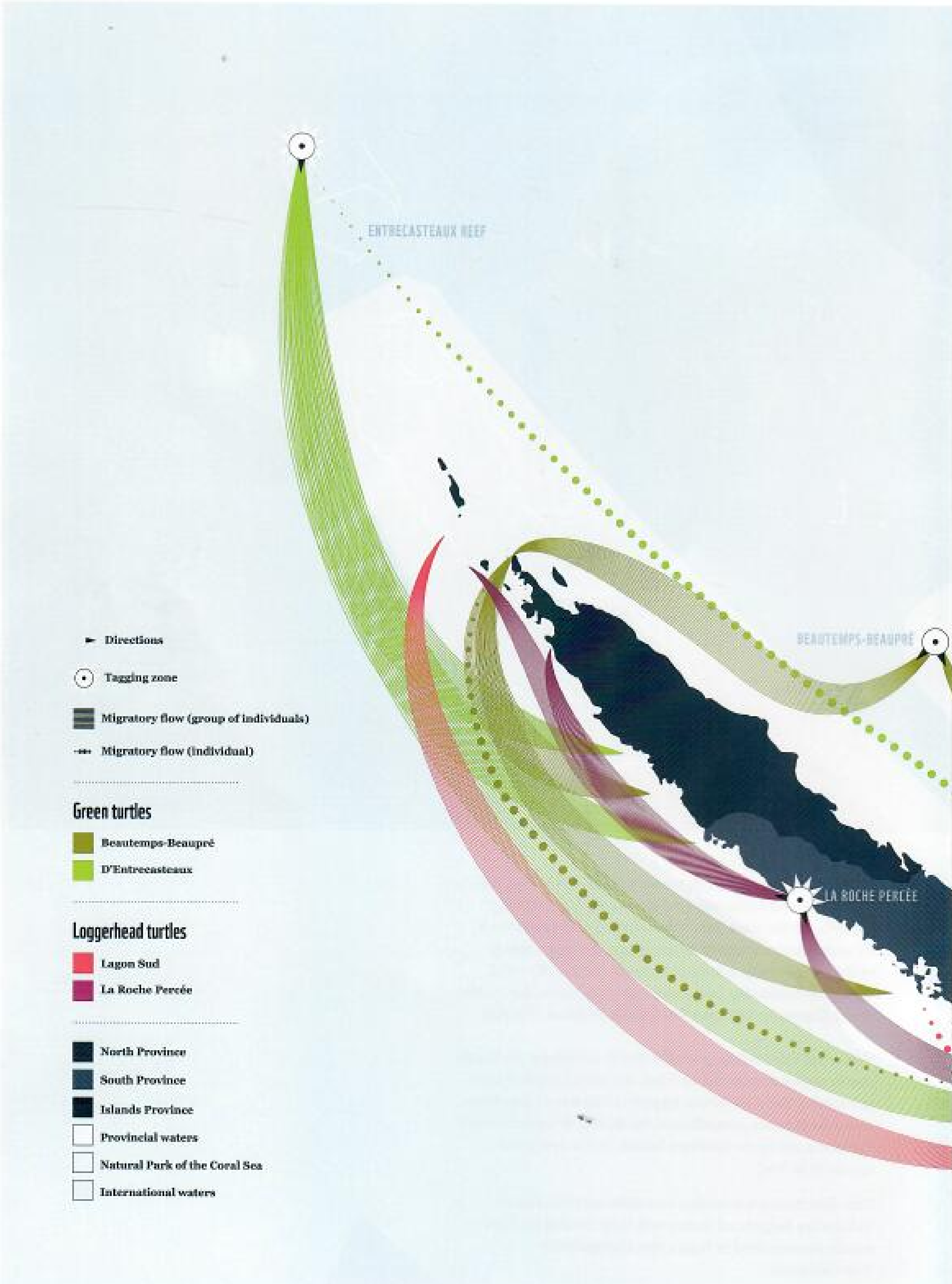
Initial knowledge on the migratory connections of New Caledonian loggerhead turtles was not as well founded as for green turtles. Therefore, SAT-NC's results provide important new insights in this respect. As opposed to green turtles, the results do not highlight any noteworthy difference in the migratory routes between the two main nesting sites studied for this species (La Roche Percée and Grand Lagon Sud). However, a new tagging effort may potentially highlight a difference. Two feeding grounds seem particularly critical for New Caledonian loggerhead turtles because they alone account for 60% of the destinations. They include the South-Eastern tip of Papua New Guinea and the West Coast of the Grande Terre of New Caledonia. The East Coast of Australia is also an important destination (25% of the turtles tagged) but the distribution of the feeding sites observed are spread over more than 2,000 km and seem much more diffuse than on the two areas previously mentioned. Lastly, although Fiji seems to be a secondary destination (approximately 10% of the destinations), this area should not be overlooked in the management considerations given the particularly critical conservation status of the population. This is all the more true as a specific feeding ground of the Fijian archipelago seems to be emerging based on the tagging data, namely the South of the main island of Viti Levu (Fig. 6).

These new results complement the knowledge already available on the loggerhead turtles from the East Coast of Australia (Perez et al. 2022) and thus complete the panorama of priority habitats for the critically endangered

South Pacific population. In terms of distribution, Australian and Caledonian turtles substantially use the same feeding grounds. On the other hand, the distribution of proportions for each country is very different. In fact, the vast majority of Australian turtles remain in Australia (over 90%) with a secondary destination (approximately 5% of the turtles) on the South-Eastern tip of Papua New Guinea (Perez et al. 2022).

Therefore, this feeding ground is clearly critical for the South Pacific population insofar as it has also been identified as a priority for New Caledonian loggerhead turtles. Connections also exist between Australia and the feeding grounds in New Caledonia and in the Solomon Islands, but at levels that appear to be low.

This distribution is therefore very different from that of Caledonian loggerhead turtles with their feeding grounds mainly concentrated in Papua New Guinea and in New Caledonia.


ENTRECASTEAUX REEF
BEAUTEMPS-BEAUPRÉ
LA ROCHE PERCÉE
Directions
Tagging zone
Migratory flow (group of individuals)
Migratory flow (individual)
Green turtles
Beautemps-Beaupré
D'Entrecasteaux
Loggerhead turtles
Lagon Sud
La Roche Percée
North Province
South Province
Islands Province
Provincial waters
Natural Park of the Coral Sea
International waters

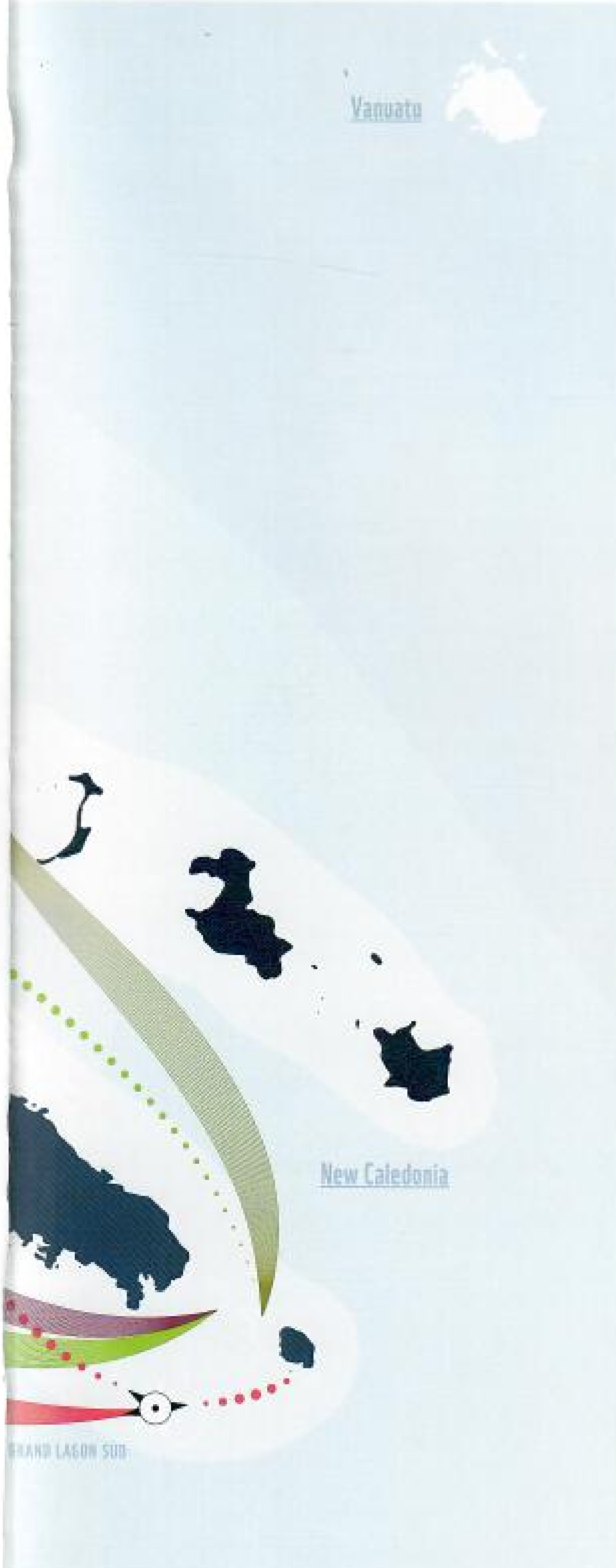


Figure 9: Migratory connections within the perimeter of New Caledonia.

MIGRATORY ROUTES

Satellite tagging is currently the simplest and most accurate method for describing the migratory behaviour of marine turtles. Thanks to this technology, key habitats can be identified even when they are located over vast ocean areas that are otherwise difficult to study. Although all of the tracks recorded indicate many possible routes and destinations, the analysis of the movements for each species and nesting site indicates, in spite of everything, the existence of areas of particular interest: the migratory corridors (Fig. 8).

For green turtles, the migratory routes are mainly concentrated on the EEZ of New Caledonia and Australia, even though incursions on Papua New Guinea, Vanuatu and Fiji have also been noted. On the international scale, two primary migratory corridors emerge between New Caledonia and Australia. They respectively lead to the feeding grounds in the North and South of the Great Barrier Reef. On the territorial scale, Entrecasteaux and the Grande Terre feeding grounds are also connected by a relatively short migratory corridor that most probably represents an important transit area during the breeding period due to the extremely large number of green turtles on this nesting site (Fretey et al. in press). The movements observed between the Beautemps-Beaupré nesting site and the Grande Terre also suggest the existence of probable migratory corridors between the two areas but more significant sampling will be necessary to confirm this (Fig. 9).

For loggerhead turtles, the routes taken to reach Papua New Guinea, the Solomon Islands or the North of Australia designate a wide migratory corridor of major importance for this critically endangered population. This corridor, which starts on the West coast of the Grande Terre, mainly leads to the North-Eastern tip of the Australian EEZ after leaving Caledonian waters, then disperses in the Southern part of the Papua EEZ. It also slightly encroaches on the Solomon Islands EEZ. The corridors leading further to the South of the Australian coast and Fiji are probably less frequented but nonetheless remain areas to be considered in management discussions. On the territorial scale, it should be noted that the West coast of the Grande Terre also represents a significant area of loggerhead turtle movements during the breeding period.

Although these ocean habitats, defined by the migratory corridors, probably constitute fewer threats than the coastal habitats, the risk and pressures caused by industrial fishing are likely to represent a major challenge for the protection of these populations. Every year, the region's longliners and seine netters cause a significant number of fisheries bycatches that are often fatal for marine turtles (Pichler 2021). The identification of migratory corridors may make it possible, if applicable, to adapt industrial fishing regulations in order to significantly reduced this pressure (Fossette et al. 2014).

4 - Exclusive Economic Zone.

WHO ARE THE MAIN CO-MANAGERS OF CALEDONIAN TURTLES?

By dealing with the two species and all of the main nesting sites in New Caledonia at the same time, SAT-NC has opted for an approach that is both institutional and ecological in order to provide managers with a global and proportionate vision of the challenges. This enables us to avoid being biased in favour of the issues at stake for which knowledge would be available. Furthermore, it also enables us to avoid justifying an inertia of the action, which may be motivated by the need for complementary data.

Despite an extremely high number of potential representatives from the South Pacific territories, SAT-NC has made it possible to draw up a restricted list of co-managers primarily involved in the conservation of Caledonian marine turtle populations.

Australia appears to be the main co-manager sharing a responsibility as regards the protection of Caledonian marine turtles. It receives a significant proportion of them in feeding grounds and protects a large part of the main migratory corridors for this species. For loggerhead turtles, it also represents a significant feeding ground and a key transit area for the North-West migratory corridor.

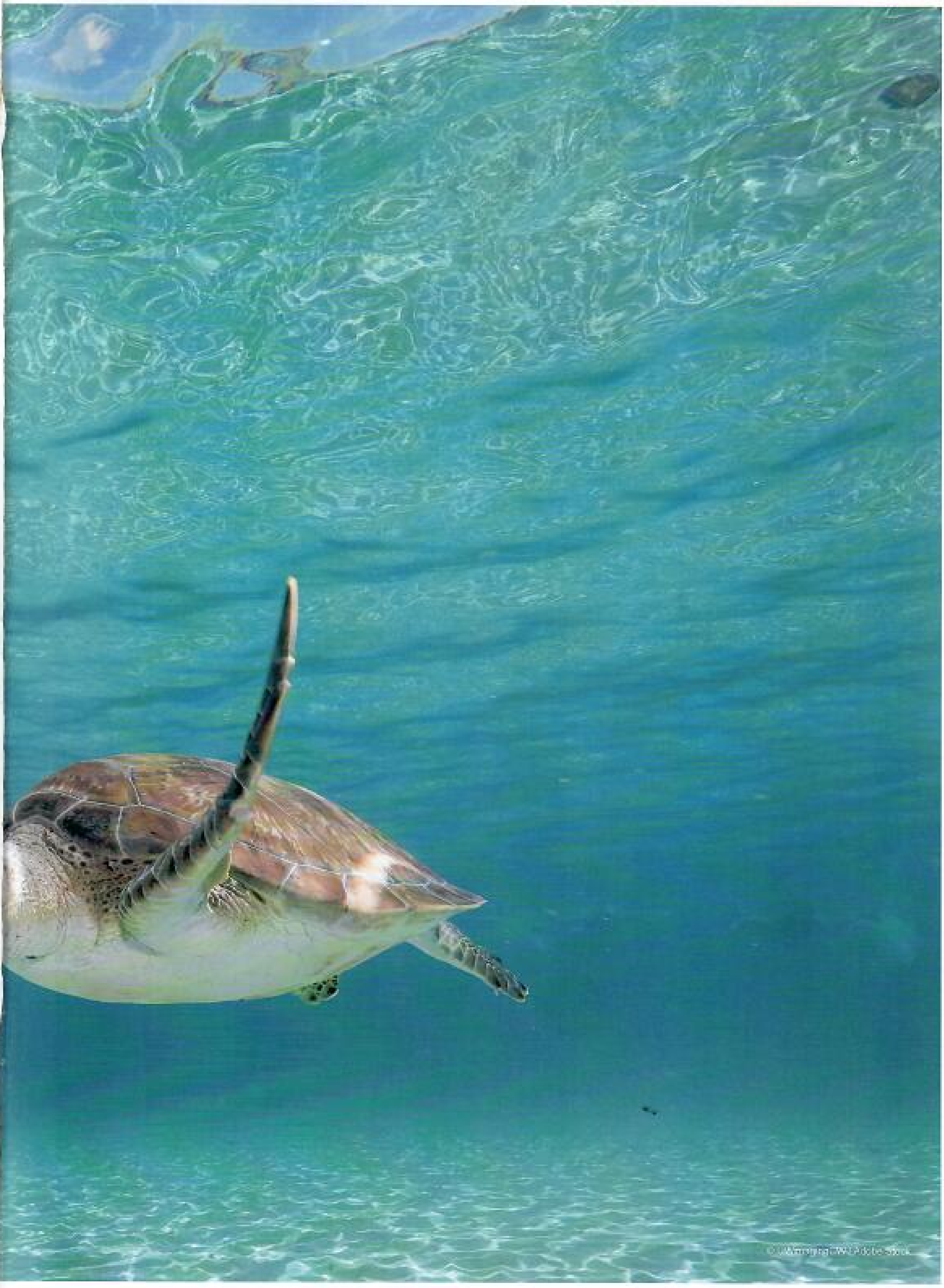
Papua New Guinea is another primary co-manager to be considered in relation to the conservation of loggerhead turtles. The South-Eastern tip of the archipelago clearly represents a key habitat for their feeding.

Fiji also represents an international partner to be considered for effective co-management of Caledonian marine turtles. Although the role of the archipelago is probably less of a priority than Australia and Papua New Guinea, the identification of a migratory corridor for loggerhead turtles towards feeding sites in the South of Viti Levu justifies this consideration.

New Caledonia

SAT-NC has highlighted a significant proportion of connections within New Caledonia's boundaries. Firstly, this concerns the transit areas passing through the Natural Park of the Coral Sea for all Caledonia nesting sites, including those located under provincial jurisdiction. This is notably the case of all of the loggerhead turtles (South and North Province) whose migration towards other countries involves passing through the Natural Park under the jurisdiction of the New Caledonia Government.

This also concerns the turtles that breed and feed within Caledonia's boundaries (35% of the turtles tagged) (Fig. 9). Apart from a few exceptions, the breeding ground and the feeding ground of these turtles are located within the boundaries of various Caledonian collectivities. These results therefore advocate the need for a territorial management of these species.



NEXT STEPS

As the results of the project are now available, they should be widely disseminated and reported, in particular with the main relevant managers, in New Caledonia and in the region.

WWF must also work on facilitating discussions between the Caledonian managers of nesting sites and the co-managers responsible for the migratory corridors and feeding grounds identified via the project.

Based on the results acquired, complementary studies may be carried out notably to assess the nature and the intensity of the threats specific to the various priority habitats identified by tagging. In particular, this will require these results to be cross-checked with other available data, such as fishing, climatic change impact modelling data, etc.

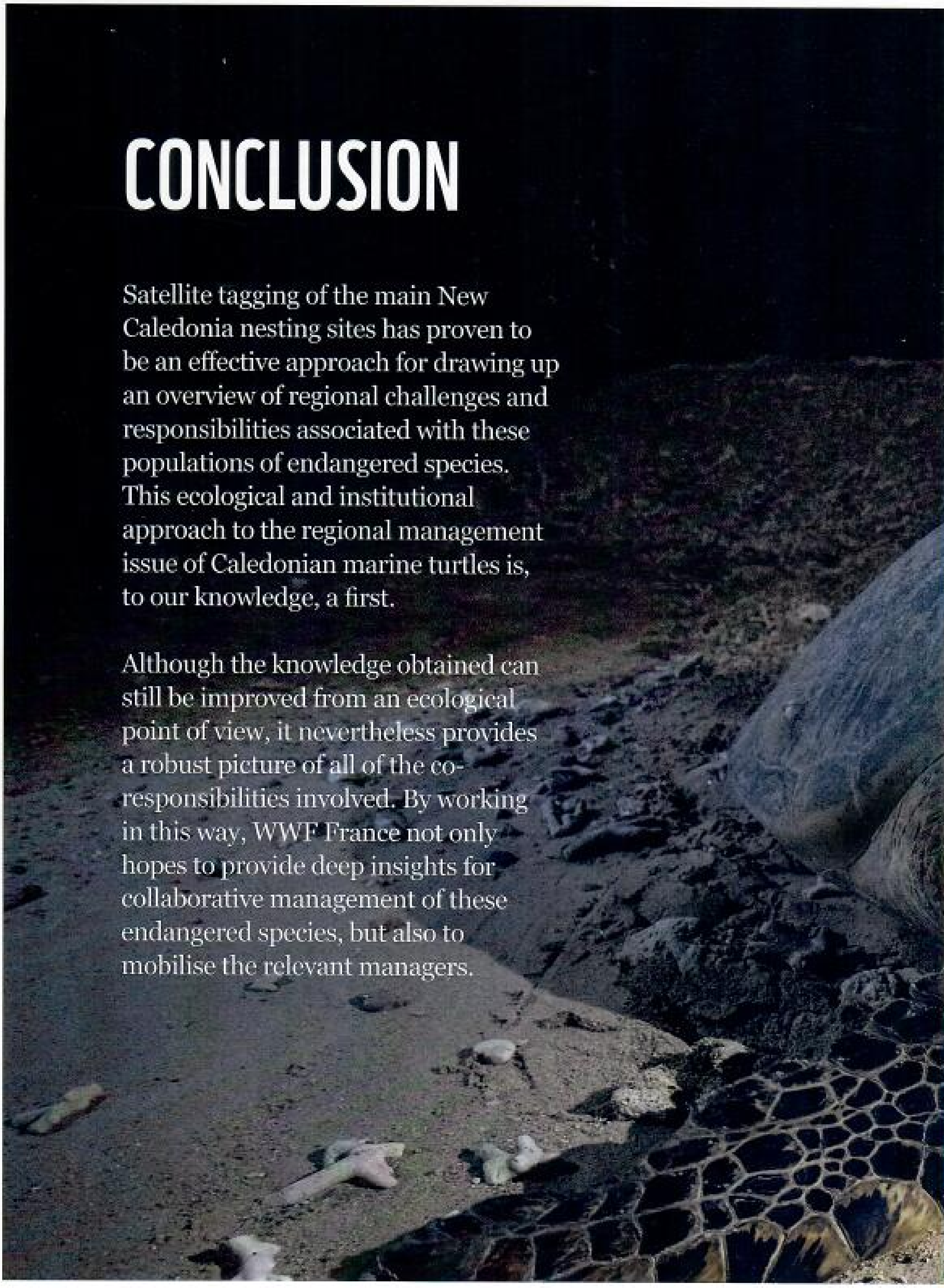
The SAT-NC project has made it possible to study the habitats of adult marine turtles that breed in New Caledonia. This approach is vital because few juvenile turtles reach the age of sexual maturity (even without anthropic threats). It is therefore absolutely necessary to protect as best as possible the individuals that have succeeded in reaching adulthood to breed and therefore contribute to population renewal. However, the first years of a marine turtle's life are also important and are subjected to many pressures caused by human activities. The SAT-NC project does not take this period into account because it does not provide information on the movements of juveniles during their lost years. For this, a different approach needs to be adopted because juvenile turtles cannot be tagged as easily as adult turtles. For this purpose, WWF, in partnership with Mercator Océan, is currently examining these issues through computer modelling of the movements of juvenile turtles (Gaspar & Lalire 2017). This complementary SAT-NC study will be the subject of another report.

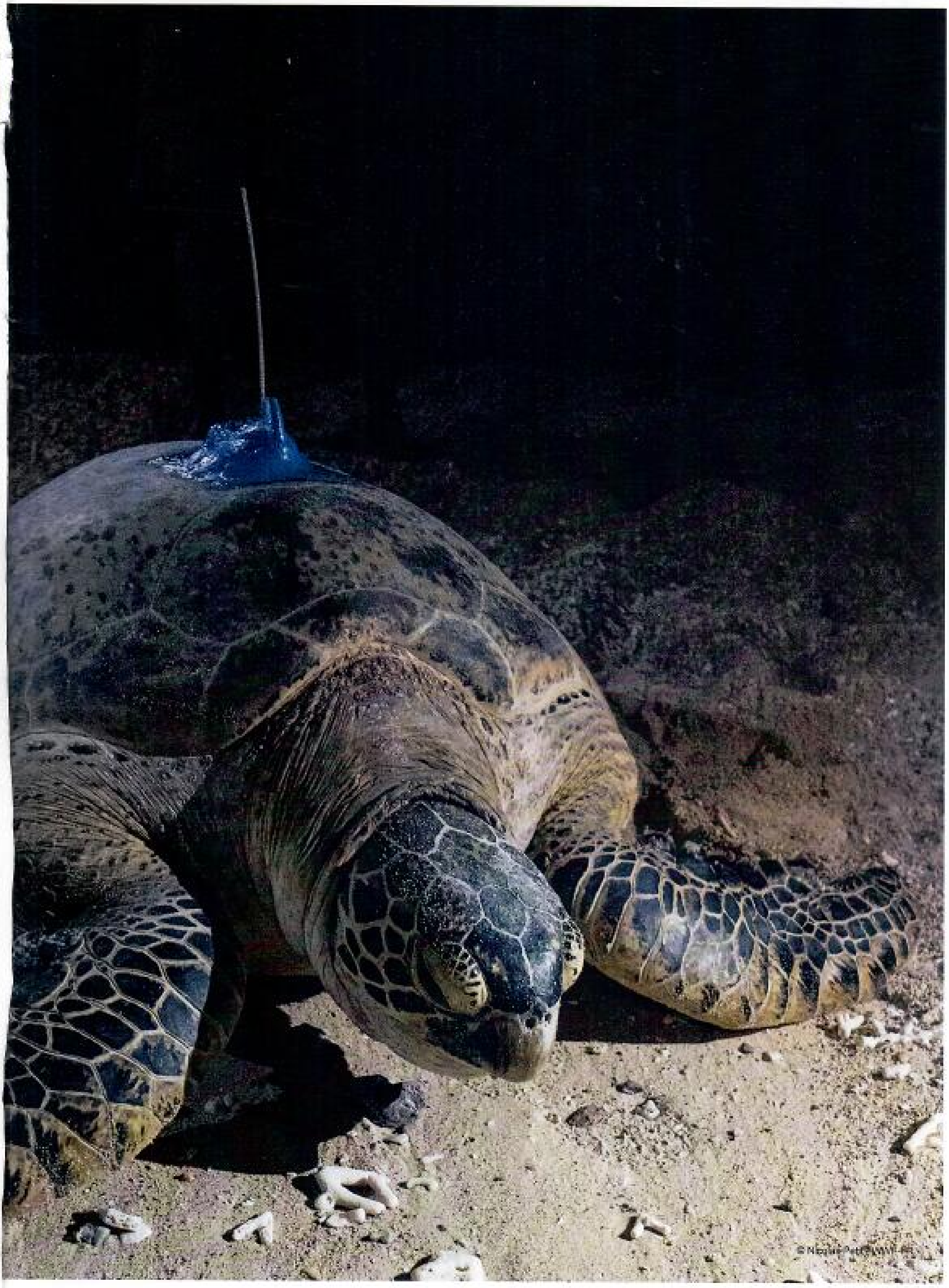
Lastly, although the SAT-NC enabled us to deploy a very large number of tags, certain nesting grounds remain under-sampled. This is particularly the case of the Lagon Nord-Ouest and Ouvéa/Beautemps-Beaupré islands. The deployment of additional tags over the coming years could help refine our understanding of priority habitats.

CONCLUSION

Satellite tagging of the main New Caledonia nesting sites has proven to be an effective approach for drawing up an overview of regional challenges and responsibilities associated with these populations of endangered species. This ecological and institutional approach to the regional management issue of Caledonian marine turtles is, to our knowledge, a first.

Although the knowledge obtained can still be improved from an ecological point of view, it nevertheless provides a robust picture of all of the co-responsibilities involved. By working in this way, WWF France not only hopes to provide deep insights for collaborative management of these endangered species, but also to mobilise the relevant managers.





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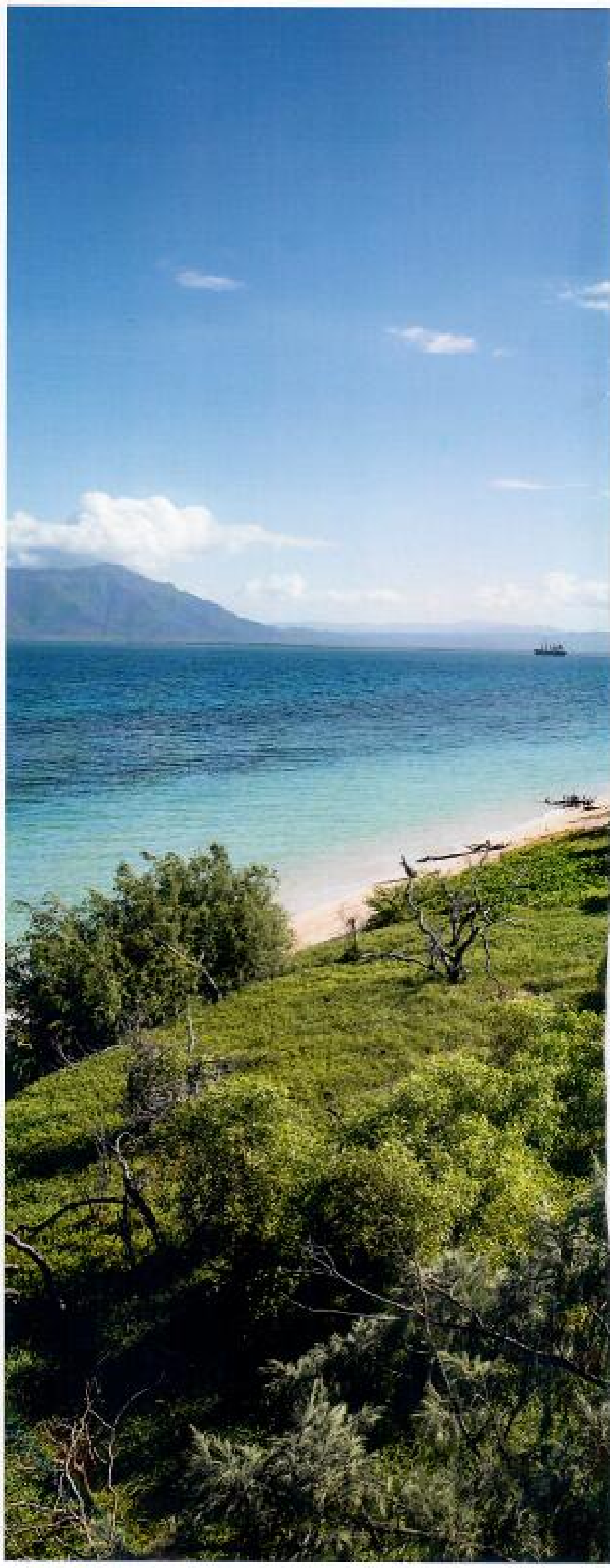


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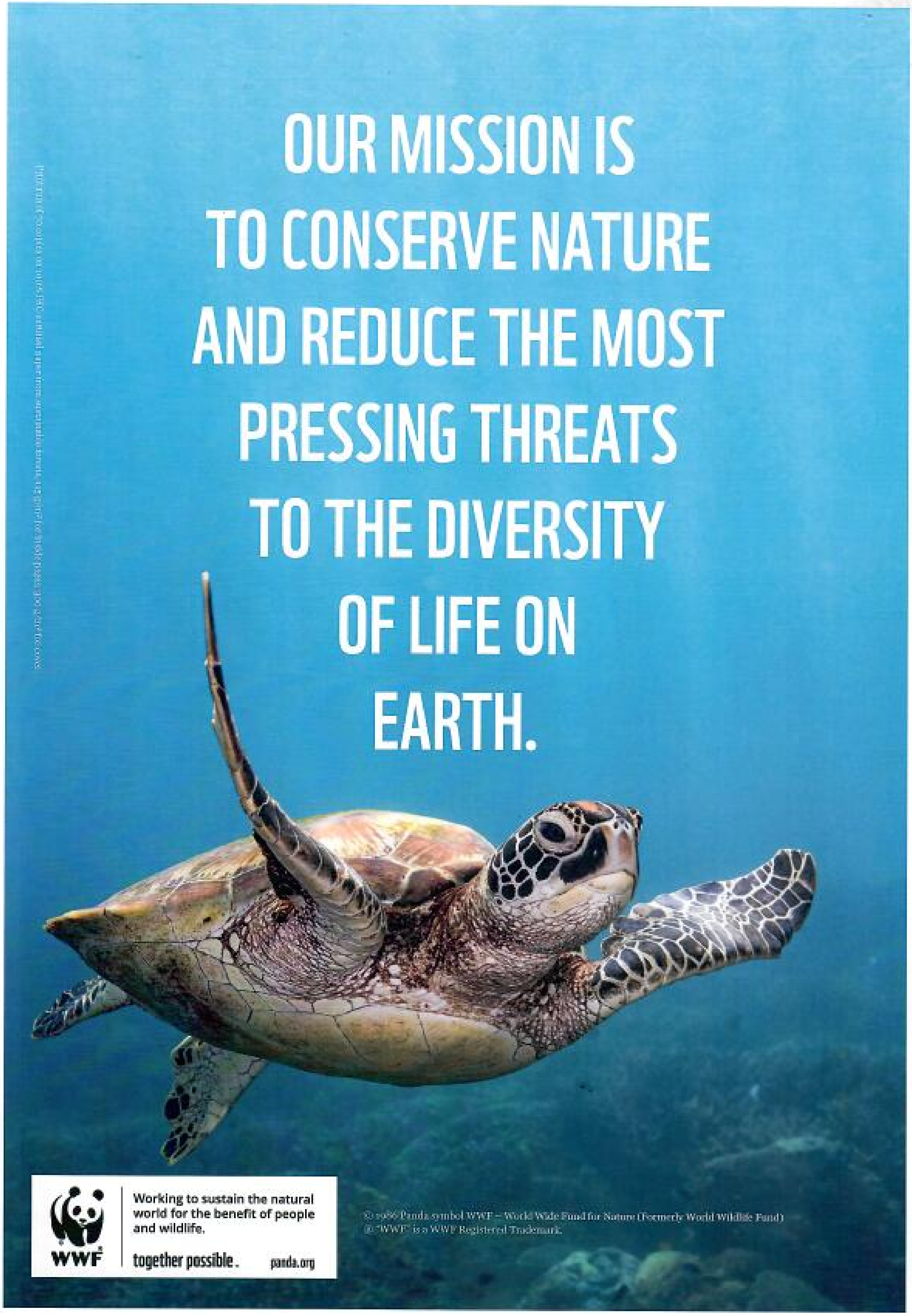
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