MARINE MANAGEMENT
GALAPAGOS REPORT 2015-2016

MARINE MANAGEMENT

ANALYSIS OF AGREEMENTS REACHED IN THE PARTICIPATORY MANAGEMENT BOARD 2010-2015

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Introduction

The Galapagos Marine Reserve (GMR) was created in 1998 within the framework of the Special Law for Galapagos (LOREG or Ley de Régimen Especial para la Conservación y Desarrollo Sustentable de la Provincia de Galápagos; CNE, 1998). Currently, the conservation of resources of the GMR is high and social conflicts have been addressed with the participation of all of its users. This article reviews participatory management of the GMR and the priorities of the Participatory Management Board (PMG) during its last six years of existence, prior to its dissolution under the 2015 reform of the Special Law (National Assembly, 2015).

While the human population in the Galapagos Islands increased gradually throughout much of the 20th century, population growth accelerated as a result of burgeoning tourism activity beginning in the 1970s. At first, the local community focused on agricultural activities, hunting, and fishing to sustain their families. Fisheries became a necessity for survival as well as a traditional activity among Galapagos residents. Fishing focused mainly on lobster and white fish, with sea cucumber harvesting beginning in the 1990s.

The enactment of the LOREG in 1998 marked an historic milestone for fisheries for two primary reasons: 1) it created the GMR, with an extension of 40 miles measured from the outer coastlines; and 2) it restricted fishing activities within the GMR to local fishermen who were affiliated with a legally constituted fishing cooperative. This initiated a fight with those involved in fisheries on the continent, especially fishermen from Manta, who were accustomed to conducting fishing operations in the Archipelago.

Only artisanal fishermen can carry out commercial fishing operations within the 40 miles of the GMR; industrial fishing is prohibited. All active fishermen must be listed in the fishing register of the Galapagos National Park Directorate (GNPD). In the year 2000, there were 682 registered fishermen; over the next five years, the number grew by 62%, to 1105 in the year 2015 (Table 1). During these 15 years, the number of fishermen ranged between 682 and 1142, with early rapid growth followed by a more stable number of approximately 1000. However in the year 2000, there were 1229 active fishermen, although only 682 were registered. Over the next 15 years there was a slow decline in the number of active fishermen, reaching only 315 active in 2014.

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1 Active fishermen are those registered fishermen who have carried out fishing activities and were monitored by GNPD personnel at the docks.
Table 1. Number of fishermen reported per year between 2000 and 2015.

<table>
<thead>
<tr>
<th>Year</th>
<th>Registered Fishermen</th>
<th>Annual Variation</th>
<th>Active Fishermen</th>
<th>% Active</th>
<th>Annual Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>682</td>
<td></td>
<td>1229</td>
<td>-44.5</td>
<td>-350</td>
</tr>
<tr>
<td>2001</td>
<td>834</td>
<td>225</td>
<td>677</td>
<td>56.4</td>
<td>-202</td>
</tr>
<tr>
<td>2002</td>
<td>1059</td>
<td>-81</td>
<td>645</td>
<td>51.6</td>
<td>12</td>
</tr>
<tr>
<td>2003</td>
<td>978</td>
<td>19</td>
<td>657</td>
<td>51.8</td>
<td>-202</td>
</tr>
<tr>
<td>2004</td>
<td>997</td>
<td></td>
<td>466</td>
<td>115.9</td>
<td>-193</td>
</tr>
<tr>
<td>2005</td>
<td>1001</td>
<td>5</td>
<td>400</td>
<td>155.8</td>
<td>-66</td>
</tr>
<tr>
<td>2006</td>
<td>1006</td>
<td>75</td>
<td>409</td>
<td>168.5</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>1023</td>
<td>-131</td>
<td>437</td>
<td>121.3</td>
<td>28</td>
</tr>
<tr>
<td>2008</td>
<td>1098</td>
<td>27</td>
<td>408</td>
<td>150.7</td>
<td>-65</td>
</tr>
<tr>
<td>2009</td>
<td>967</td>
<td></td>
<td>473</td>
<td>110.1</td>
<td>-36</td>
</tr>
<tr>
<td>2010</td>
<td>994</td>
<td></td>
<td>410</td>
<td>164.4</td>
<td>2</td>
</tr>
<tr>
<td>2011</td>
<td>1023</td>
<td>29</td>
<td>316</td>
<td>255.7</td>
<td>-94</td>
</tr>
<tr>
<td>2012</td>
<td>1084</td>
<td>61</td>
<td>315</td>
<td>262.5</td>
<td>-1</td>
</tr>
<tr>
<td>2013</td>
<td>1124</td>
<td>18</td>
<td>468</td>
<td>136.1</td>
<td>153</td>
</tr>
<tr>
<td>2014</td>
<td>1142</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>1105</td>
<td>-37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Participatory management**

The concept of participatory management was one of the most important advances of the LOREG. Article 73 of the LOREG defined participatory management as: “The situation in which some or all interested stakeholders of a protected area are substantially involved in management activities.” Based on this law, management decisions were to be taken by mutual agreement of interested parties and not exclusively by the the environmental authority.

Paragraph 6.3.1 of the LOREG states that the Participatory Management Board (PMB) “will be composed of the following representatives of the local direct users of the Marine Reserve or its delegates”: 1) the official representative of the artisanal fisheries sector (chosen from among the four presidents of the Galapagos fishing cooperatives); 2) the representative of the Galapagos Tourism Chamber or its delegate, representing the tourism sector; 3) the Charles Darwin Research Station (CDRS), and 4) the Galapagos National Park Directorate (DPNG). The General Application Regulation of the LOREG was issued in 2000. Article 47 defined the members of the PMB, including two additional members — the conservation, science, and education sector, and a representative of the naturalist guides of Galapagos. It also stated that the permanent members of the Board could by consensus define other permanent members.

In 2006, the Technical Committee for Fisheries (TCF) was created to assist the GNPD and the PMB in the analysis of scientific information that might be useful for the formulation and management of fishery resources, to evaluate the progress of agreed upon goals, and to provide support in identifying priorities for research and fisheries development.

Article 15 of the LOREG also indicated that the GNPD would be responsible for developing the GMR management plans, and explicitly dictated that the Park would define, via the PMB, the local alliances and levels of participation and responsibility of properly organized user groups. The Management Plan of the GMR was developed in this manner and was approved in 1999, defining permitted activities and the regulations and administration of the GMR, among other issues (DPNG, 1999).

Since its inception, participatory management sought to resolve conflicts by creating consensus for the management of the GMR. The greatest conflicts arose in the years 1999, 2000, 2002, and 2004, and were mainly related to sea cucumber and lobster fisheries. Although the PMB dealt with a wide range of issues, fisheries was the primary focus. Between 2010 and 2015, the PMB held 29 meetings — five in each year except 2010, when there were only four. PMB regulations called for an annual plan of activities. For the period 2010-2015, 108 topics were scheduled for discussion. However, only 36 of the proposed subjects were addressed, along with 49 additional topics. In all, 85 topics were presented over the six-year period.

Since the enactment of LOREG in 1998, there have been six presidential administrations. In 2008, during the term of President Rafael Correa, a new Constitution was adopted, and in 2010, the Organic Code of Territorial Organization, Autonomy and Decentralization (COOTAD – Spanish acronym) was adopted. Both the 2008 Constitution and the
COOTAD justified the Special Regime for Galapagos based on environmental considerations. These laws mandated a reform of the 1998 LOREG, which was completed in June 2015 (General Assembly, 2015). In this reform there is no mention of participatory management, although citizen participation is recognized. Similarly, the reformed LOREG transforms the PMB into a Participatory Management Advisory Council (PMAC), with a non-binding advisory role. The PMB, as such, functioned for 17 years.

Analysis of the resolutions

Paragraphs 6.3.2 and 6.3.3 of the GMR Management Plan detail the 42 functions of the PMB, including 16 general functions (Table 2) and 26 specific functions (Table 3; DPNG, 1999). The specific attributes include ten related to fisheries, six in tourism, six in educational support, two in control, and two in science.

Table 2. General functions of the Participatory Management Board (DPNG, 1999).

<table>
<thead>
<tr>
<th>Subsection</th>
<th>General Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Analyze and propose to the GNPD specific matters related to the Galapagos Marine Reserve that do not interfere with the jurisdiction of the Inter-institutional Management Authority (AIM – Spanish acronym), or that have been delegated to AIM, INGALA, or another institution.</td>
</tr>
<tr>
<td>b</td>
<td>Participate in the evaluation of the effectiveness of the Plan, according to the monitoring and evaluation program for the implementation of the Management Plan.</td>
</tr>
<tr>
<td>c</td>
<td>Analyze and propose changes in the Management Plan.</td>
</tr>
<tr>
<td>d</td>
<td>Support the revision of the Management Plan.</td>
</tr>
<tr>
<td>e</td>
<td>Assess and monitor compliance with the Plan.</td>
</tr>
<tr>
<td>f</td>
<td>Identify technical support needs for decision-making and discussion.</td>
</tr>
<tr>
<td>g</td>
<td>Analyze and propose revisions of Marine Reserve zoning.</td>
</tr>
<tr>
<td>h</td>
<td>Ensure the integration of the marine and terrestrial management plans.</td>
</tr>
<tr>
<td>i</td>
<td>Ensure compliance of environmental impact studies for activities within the GMR.</td>
</tr>
<tr>
<td>j</td>
<td>Review and analyze the results of the environmental impact assessments carried out within the GMR and propose recommendations.</td>
</tr>
<tr>
<td>k</td>
<td>Coordinate the participation of users in the management of the Marine Reserve, by means of management and administration programs and subprograms referred to in the Management Plan.</td>
</tr>
<tr>
<td>l</td>
<td>Promote the development of educational and scientific use of the Marine Reserve.</td>
</tr>
<tr>
<td>m</td>
<td>Analyze and propose new activities.</td>
</tr>
<tr>
<td>n</td>
<td>Design and propose a system and procedures for evaluating new uses, users, and modalities within the Galapagos Marine Reserve.</td>
</tr>
<tr>
<td>o</td>
<td>Participate in the elaboration of proposals for reforms to the laws and regulations related to the activities and uses within the Galapagos Marine Reserve.</td>
</tr>
</tbody>
</table>

Table 3. Specific functions by theme of the Participatory Management Board (DPNG, 1999).

<table>
<thead>
<tr>
<th>Topic</th>
<th>Subsection</th>
<th>Specific Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing</td>
<td>a</td>
<td>Establish criteria and procedures to analyze and propose definitions of fishing methods as well as definitions, ratings, tonnage, and capacity of vessels.</td>
</tr>
<tr>
<td>Fishing</td>
<td>b</td>
<td>Analyze and propose fishing methods, tonnage, and capacity of vessels, based on the criteria established in the Management Plan.</td>
</tr>
<tr>
<td>Fishing</td>
<td>c</td>
<td>Identify monitoring and research needs, analyze results and propose recommendations.</td>
</tr>
</tbody>
</table>

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2 Special Law 2015, Article 3, Principle 4. Citizen participation. Citizens, individually and collectively, will participate in a leading way in decision-making, planning and management of the Special Regime of Galapagos, in accordance with the Constitution and the law.

3 Special Law 2015, Article 22. Participatory Management Advisory Council. The Advisory Council is a citizen participation organism that provides non-binding advice to the administration and management authorities of the marine reserve in the Galapagos province. Its formation shall be governed under the rules indicated in the regulation issued by the Governing Council of the Special Regime of Galapagos.
Between 2010 and 2015, 75% of the resolutions of the PMB referred to specific powers of the PMB; of these, more than three-quarters related to fisheries (Figure 1).
Of the general functions of the PMB, “zoning of the GMR” (subsection “g”), and “participation in the preparation of proposals for reforms to the laws and regulations related to activities and uses within the GMR” (subsection “o”), were the functions with the most resolutions (five each), followed by “proposals to the GNPD on specific subjects of the GMR” (subsection “a”; Table 4).

Three of every four resolutions on specific functions were related to fisheries (Figure 2).

Table 4. Number of resolutions from 2010-2015 according to general functions of the PMB established in the Management Plan for the GMR.

<table>
<thead>
<tr>
<th>Subsection of the Management Plan</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
<th>l</th>
<th>m</th>
<th>n</th>
<th>o</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Resolutions</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>21</td>
</tr>
</tbody>
</table>

The function related to fishing in the Management Plan of the GMR (subsection “d”) states that the PMB should “analyze and propose to the managing authority fishing calendars, volume, size, species, and fishing methods allowed in Galapagos, based on information obtained from the research and monitoring program of the Management Plan, or on other relevant sources” (Figure 3). Therefore, it is understandable that this function received the greatest attention given that fishing activities depend on the openings and closures of fisheries as defined by the PMB. For the same reason, the function related to monitoring the population status of species of commercial interest (subsection “i”) was second in terms of attention received.

Of the functions included in the tourism section of the Plan, “Participate with the Advisory Board, established in Article 48 of the LOREG, in planning tourism activities with the participation of the local community” (subsection “g”) was not taken into account. The functions of educational support were also not taken into account, except for subsection “b”, which refers to “participation in the coordination of educational programs at the provincial level on the management and conservation of the Marine Reserve.” Finally, no resolutions were made related to the two subsections focused on science.

A summary of the number of resolutions that respond to the specific functions of the PMB shows that no resolutions were made with regard to several subsections (Table 5).
Figure 3. Percentage of resolutions of the PMB related to fishing (subsection “d”) and other themes, from 2010-2015.

Table 5. Number of resolutions related to the specific functions of the PMG established in the Management Plan for the GMR.

<table>
<thead>
<tr>
<th>Subsection of Management Plan</th>
<th>6.3.3.1. Fishing</th>
<th>6.3.3.2. Tourism</th>
<th>6.3.3.3. Educational support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Resolutions</td>
<td>a b c d e f g h i j</td>
<td>Total</td>
<td>a b c d e f g h i j</td>
</tr>
<tr>
<td>1 3 7 19 0 4 2 2 10 2 50 4 1 0 1 2 3 0 11</td>
<td>0 1 0 0 0 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subsection of Management Plan</th>
<th>6.3.3.4. Control</th>
<th>6.3.3.5. Science</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Resolutions</td>
<td>a b Total a b Total</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>1 1 2 0 0 0 64</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

Article 242 of the 2008 Constitution states that “… for conservation, ethnic-cultural, or population reasons, a special regime may be established. The autonomous metropolitan districts, the province of Galapagos, and indigenous and multicultural territorial constituencies will be special regimes.” Article 72 of the COOTAD states that “the special regimes are forms of government and administration of a territory, constituted for population, ethnic-cultural, or environmental conservation reasons. Its conformation will take place within the political framework of the State. The autonomous metropolitan districts, the indigenous territories, Afro-Ecuadorian and montubio districts, and the province of Galapagos are special regimes.”

The special regime is a way of managing a territory by establishing policies and actions that are connected to the realities of the territory, especially in terms of its resources and local actors. Participatory management faced serious challenges during the years when the PMB was active; however, it managed to make the necessary decisions for the conservation and sustainable development of the GMR.

We can conclude that the issues dealt with by the PMB, such as fisheries, were of direct interest to users and thus appeared most frequently in the PMB’s agendas. A number of issues remain for discussion by the Advisory Council, established in the LOREG reform of 2015. The LOREG states that “the Advisory Council is an agency of citizen participation and non-binding advice for the administration and management of the marine reserve of the Galapagos province.”

Recommendations

Citizen participation within the management framework of the GMR has made it possible to deal with many
conflicts because it dealt primarily with the fisheries issues of greatest concern to the fisheries sector. It is recommended, therefore, that the Advisory Council be consolidated as an agency for participatory management. In the same sense, the Advisory Council must constantly incorporate planning and evaluation mechanisms in order to fulfill all functions and responsibilities for which it was created.

References


GALAPAGOS REPORT 2015-2016

MARINE MANAGEMENT

FROM RESISTANCE TO ACCEPTANCE: CHANGED PERSPECTIVES OF THE GALAPAGOS MARINE RESERVE AMONG MANTA’S TUNA FISHERMEN

Nadine Kliffen, Jessica Clara Maria Berkes and Jorge Ramirez González

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From resistance to acceptance: Changed perspectives of the Galapagos Marine Reserve among Manta’s tuna fishermen

Nadine Kliffen, Jessica Clara Maria Berkes and Jorge Ramírez González

World Wide Fund for Nature

Introduction

For centuries, oceans have been seen as public property, open to exploitation. Garett Hardin argued in 1968 that in a world with rapid population growth a common resource could not be used without limitations; continued use of the ocean as an inexhaustible resource would result in a Tragedy of the Commons (Hardin, 1968). One solution would be to stop viewing the ocean as infinite and thus change the perspective on the right to fish, in other words, to regulate fisheries (Hardin, 1968; Ostrom, 2008; Brooks et al., 2014).

Today, almost 50 years after Hardin wrote his famous essay, well-designed and actively managed Marine Protected Areas (MPAs) are one of the most effective solutions to protect marine ecosystems (Hastings et al., 2012). Simultaneously, they can be effective in maintaining fisheries over the long term, contributing to sustainable development. The contemporary perspective on MPA design and management is that all stakeholders must be included in the process, which is often a challenge.

Reducing fishing efforts worldwide is one of the recommendations of the United Nations (2007) to achieve sustainable fisheries. MPAs, which are relatively well accepted among stakeholders, can contribute to this by establishing clear fishing regulations, such as exclusive fishing rights for local people. Initially most MPAs were managed from a scientific point of view, the top-down approach (Jones, 2001). Today, it is recognized that the benefits of MPAs should be acknowledged by both the fishing and scientific communities to be effective, and must be beneficial to the ecosystem. Contemporary management systems of MPAs include stakeholders to a greater extent than previously, leading to a greater sense of responsibility for the area’s resources among communities. MPAs are increasingly perceived as a part of a socioecological system in which ecological objectives cannot be separated from socioeconomic interests (Jones, 2014).

MPAs are considered to benefit fisheries due to the ‘spillover effect’ theory: when fish stocks increase within a marine reserve, the fish migrate outside of the MPA. Moreover, the average size of fish increases. Many empirical studies support the theory of spillover effects, but there is still little evidence on the impacts of MPAs on highly migratory species, such as tuna (Grüss et al., 2011). Therefore, additional analyses are needed to establish the benefits of MPAs and to educate those involved in fisheries that are external to the MPA.

When the Galapagos Marine Reserve (GMR) was established in 1998, industrial fisheries were excluded from the waters around the Galapagos Islands. During the period leading up to the establishment of the GMR, there was major conflict between those involved in the establishment of the GMR and the representatives...
of Ecuador’s tuna industry. Although the tuna industry representatives were eventually excluded from the dialogue, they had to obey the regulations of the MPA once it was established. This case study shows that over time Manta’s tuna fishermen grew to perceive the GMR more positively—as a breeding ground for tuna that supports their fishery over the long term. This article is based on an ethnographic case study of the industrial tuna fishermen in Manta, Ecuador, and describes their perspective on the GMR.

Manta’s tuna industry

Manta’s tuna industry is one of the four most important components of Ecuador’s economy, along with petroleum, bananas, and shrimp cultivation (Vega & Beillard, 2015). More tuna are exported than any other fish species. With 25,000 people working in the industry, it represents a considerable contribution to socioeconomic well-being. This study focuses on the skipjack tuna fishery as it is the most common species caught by purse seiner vessels in Manta (Figure 1). Other important species caught industrially include bigeye tuna and yellowfin tuna (Vega & Beillard, 2015).

The IUCN Red List identifies skipjack tuna as a species of “least concern” in the Eastern Pacific Ocean (EPO), although variable reproductive rates and catch methods complicate estimates. Despite a significant increase in catches in the last ten years, the number of skipjack tuna remains sufficient in the EPO. However, the average weight of an adult skipjack tuna is decreasing and by-catch is a significant problem (Collette et al., 2011).

Ecuadorian flagged vessels caught half of the 500,000 mt of tuna reported arriving in the harbor of Manta in 2015 (IATTC, 2016). Currently, there are 117 Ecuadorian vessels officially registered as purse seiners; the Associate of Tuna Fishermen of Ecuador (ATUNE – Spanish acronym) represents the owners of these vessels. In a city with approximately 250,000 inhabitants, an industry of this size implies a major income source for the inhabitants of Manta. Most contemporary Manta fishermen belong to families that have fished for generations.

The establishment of the GMR

In 1997, the Galapagos National Park Directorate (GNPD), the governance organ of the protected areas of the Islands, initiated meetings with different stakeholders of the marine area, eventually leading to the revision of the management plan of the marine reserve (GNPD, 1998). According to the GNPD, Manta’s tuna industry responded to these developments with a strong statement indicating that they would never obey the new regulations and would continue fishing in the future reserve. Their statement gave rise to increased collaboration between different actors in Galapagos (GNPD, fishing cooperatives, naturalist guides, tourism organizations, and NGOs) to develop the GMR and its new management plan as a group, excluding the tuna industry.

The GMR (138,000 km²) was officially established in 1998 (Jones, 2014) and has functioned with a co-management system since 1999 (Heylings & Bravo, 2006). This participatory system includes various stakeholders in the management process, with the role of each stakeholder ranging from providing feedback to active participation. Although participatory systems are based on the idea that all stakeholders participate (Jones, 2014), the GMR’s management system has consistently excluded the industrial fishing industries, including Manta’s tuna industry. Although ATUNE was invited to the initial meetings that led to the establishment of the GMR, the cooperative refused to participate (Kliffen & Berkes, 2014).

Figure 1. Skipjack catches in the harbor of Manta. Photo: Juan Sebastian Rodriguez Cadena
Methods

This study of the perceptions of Manta’s tuna industry towards the GMR employed qualitative research methods, including participant observation and in-depth interviews, over a period of three months in the summer of 2013. The primary target group included fishermen (crew), captains, boat owners, and technical staff working in the harbor (i.e., engineers). Interviews with the wives of fishermen were conducted to support the information provided by their husbands. To gain a broader perspective, interviews also took place with individuals working in NGOs, COPROPAG (the fishing cooperative of Santa Cruz Island, Galapagos), the GNPD, and the Inter-American Tropical Tuna Commission (IATTC) in Manta (Table 1). In total 45 respondents were interviewed formally, often more than once; these interviews were supplemented with informal conversations and observations (Figure 2).

Table 1. Number of Interviewees per research group.

<table>
<thead>
<tr>
<th>Group No.</th>
<th>Description of group</th>
<th>No. Interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>People working in the tuna industry: fishermen, captains, boat owners, and harbor employees (main research group)</td>
<td>28</td>
</tr>
<tr>
<td>2</td>
<td>Family members of fishermen</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Biologists working as IATTC observers</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Conservationists from NGOs in Galapagos and the GNPD</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 2. Interview with a boat owner in the harbor of Manta. Photo: Nadine Kliffen

Results

The impact of the GMR on the tuna industry

Today, many marine scientists consider the inclusion of stakeholders in MPA establishment and management processes crucial for success (i.e., Jones, 2001; Ostrom, 2008). In the case of the GMR, the tuna industry did not take part in the discussions leading up to the establishment of the MPA, which in turn benefited local stakeholders: the tourism industry and local fishermen. Respondents of this study expressed the view that there was insufficient communication between all stakeholders during and after the establishment of the GMR. For the fishermen, their main source of information was their captain; they indicated that no information about the establishment of the GMR was distributed to them on land. Fishermen agreed that they received no information from boat owners, the government, or NGOs. These communication gaps increased the feelings of exclusion and a general lack of understanding about the existence and regulations of the MPA. Moreover, because Galapagos had been one of their major fishing grounds for decades, the ban to enter the area caused them to feel insecure about their future livelihood.

The loss of the Galapagos as a primary fishing area for the Manta tuna industry caused them to search for other fishing grounds. After 2002, tuna vessels began to fish in waters farther from the Ecuadorian coast. The area southwest of the Galapagos Archipelago was indicated as a fertile fishing area by the majority of the respondents, which possibly confirms spillover effects from protection of marine wildlife in the GMR. During this same period, onboard technology improved, including the use of Fishing Aggregating Devices (FADs)—artificial floating objects that attract fish, which include a satellite system that registers the location of the object, the amount of
tuna in the area, and other details. Manta’s tuna industry perceives FADs as an important tool that helped them overcome the loss of the Galapagos fishing ground (Figure 3). In addition, because of the increased size of the vessels, they are able to store tuna for a longer period of time and therefore fish in more distant waters. One downside mentioned was that they are now away from their families for longer periods of time.

Figure 3. A photo of a satellite system of a mid-size purse seiner vessel, screening its FADs. Photo: Juan Sebastian Rodríguez Cadena

**Imposed regulations and unintended education**

During the first years following the establishment of the GMR, surveillance in the region was limited due to a lack of resources and illegal industrial fishing was a significant problem. With increased resources around 2002, the GNPD improved surveillance throughout the GMR, the sanctions for entering the GMR illegally became more effective, and illegal fishing decreased. Industrial vessels entering the GMR risked confiscation of their vessel and imprisonment of the crew. Today, because of the efficient control and high sanctions, the purse seiner tuna industry perceives the GMR as not worth entering.

In the GMR, increased regulations and control had a positive outcome in conservation terms, but also led, indirectly, to a change in the perspectives of sustainable fishing among tuna fishermen on the continent. As argued by Jones (2014), an MPA, in addition to protecting a specific area, can be a tool for increasing awareness of marine protection. The establishment of a new reserve provides an opportunity to educate stakeholders about why the area needs protection and how the reserve can benefit them. In the case of Galapagos however, this educational opportunity was missed in relation to the tuna fishermen of Manta. What eventually began to change their perspective was the obligation imposed by the IATTC that all vessels with a capacity of more than 350 tons must take an IATTC supervisor onboard. These biologists not only recorded catches and coordinates, they also checked on by-catch and garbage thrown overboard; interacting with them throughout the trip increased the fishermen’s awareness and understanding of sustainable fishing (Figure 4).

Today, a large majority of the respondents, especially fishermen, realize that the ocean’s resources are not inexhaustible and they accept that regulations are necessary to preserve their profession. Of the main research group, 73% accepted and/or appreciated the existence of the GMR and 49% mentioned the MPA directly or indirectly as a breeding ground. Boat owners were the most critical towards the GMR, while fishermen (crew) and captains were the most positive. Whereas the establishment of the GMR in 1998 was seen as a threat to the future of the industrial tuna fishery, today the MPA is perceived as a breeding ground for tuna that supports the fishery.

**Conclusions**

During the long process to establish the GMR, the tuna industry of Manta strongly rejected the new regulations. The representatives of the industry stated that they would never obey the new regulations related to the MPA, resulting in their total exclusion from the development process. Sixteen years later, however, Manta’s tuna industry generally accepts the GMR and understands its long-term benefits for the tuna industry. This changed perspective is influenced by the effective control of the GMR and the presence of IATTC observers onboard the fishing vessels, which have had an unintended but beneficial educational effect on the fishermen. More efficient fishing methods, in particular the use of FADs, also supported the changing perspective on the GMR.

In contrast to the contemporary shared opinion, this study shows that inclusion of all stakeholders in the establishment and management process is not always a necessity for
acceptance of a MPA. However, any stakeholder exclusions may cause that acceptance to take much longer.

**Recommendations**

Although in the case of the GMR the outcomes were eventually positive, we explicitly do not recommend excluding any stakeholders in MPA establishment and management. The determination of which stakeholders to include must be based on the specific situation; open and effective communication with all stakeholders at all levels is important in all cases. Although ATUNEC was invited to meetings about the GMR, the communication between ATUNEC and boat owners and their crew were limited. While this may have been a lack of communication on the part of ATUNEC, we recommend that those responsible for the establishment of MPAs strive to not only inform corporations or similar bodies, but also ensure that all stakeholders be well informed about the advances in strategies and plans. Ensuring effective communication and education at all levels leads to better cooperation and decreases the need for control; it also increases general awareness and acceptance of the importance of marine protection.

**Acknowledgements**

The project initiators greatly appreciate the support from WWF Netherlands, WWF Ecuador, Dr. F. Colombijn from VU University, and Vamos Bien Foundation. Without their financial, academic, and practical contributions, this study would not have been possible.

This project also produced audio-visual material:

- El Criadero: https://www.youtube.com/watch?v=5Sa8HLV03AA
- MPAs myths dismantled: marine reserves can benefit industrial fisheries: https://www.youtube.com/watch?v=1Tg4-y4uZEq

**References**


GALAPAGOS REPORT 2015-2016

MARINE MANAGEMENT

THE DANGER OF CARIOJA RIISEI INVADING THE GALAPAGOS MARINE RESERVE

Inti Keith and Priscilla C. Martinez

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The danger of *Carijoa riisei* invading the Galapagos Marine Reserve

Inti Keith¹ and Priscilla C. Martinez²

¹Charles Darwin Foundation, ²Nazca Institute for Marine Research

**Introduction**

*Carijoa riisei*, also known as snowflake coral, is native to the Indo Pacific and has been widely spread in the Hawaiian Islands causing significant ecological impact since it was first detected at Pearl Harbor in 1972 (Concepción *et al*., 2010). Its rapid growth rate and vegetative reproduction allows this species to achieve high densities, and compete with and displace native fauna, causing substantial impact (Kahng *et al*., 2008). *C. riisei* was first reported in the coast of Ecuador in 2011 (Martinez *et al*., 2011). Since then, it has spread along the coast and is causing ecological impact to the biological communities in the region. It has also been reported in the islands of Malpelo, Colombia (Sánchez *et al*., 2011), located 500 km west of continental Colombia and about 1200 km northwest of Darwin Island in the Galapagos Marine Reserve (GMR). Similar to many other marine invasive species it is thought that the main vector for translocation of *C. riisei* is through bio-incrustation on the hulls of boats (Eldredge & Smith, 2001).

The research presented here demonstrates how this high-risk species could spread from continental Ecuador to the GMR and provides recommendations to ensure it never becomes established in the Archipelago. The analysis includes a thorough examination of dispersal mechanisms and established shipping routes. Because of the recognized devastating impacts to native biological communities, prevention, potential early detection, and rapid response protocols were evaluated to then recommend best practices to prevent the arrival and establishment of *C. riisei* in the GMR.

**Marine traffic**

The continuous increase of marine traffic to the Galapagos Islands spreads the risk of arrival of non-native species to this region, where the isolation in which species have evolved makes them more vulnerable to competition with non-native species. Marine traffic is a prime example of an anthropogenic vector; shipping vessels can act as biological islands for species that live in harbors around the world (Wonham *et al*., 2001). The Galapagos Archipelago has received vessels from around the world since its discovery in 1535, and as tourism, trade, and transport rise due to globalization the amount of marine traffic entering the GMR has increased as well. Cargo ships, private yachts, research vessels, patrol boats, and illegal fishing boats are the main types of vessels entering the GMR (Keith *et al*., 2016).

Continued growth in both population and tourism has increased the demand for cargo that is shipped from the continent to the Islands, thereby augmenting
the number of ships needed. All cargo ships that travel from the continent to the GMR do so from Store Ocean, which is a natural river port located on the banks of the Rio Guayas. Although the brackish water of the Rio Guayas can act as a barrier for many species that cannot tolerate the change in salinity, the risk of non-native species translocation still exists as there are high-risk invasive species worldwide, such as the European green crab (*Carcinus maenas*) and the blacked-striped mussel (*Mytilopsis sallei*), that can support a wide range of salinity and high levels of pollution, and successfully settle and proliferate in new environments.

Ecuador has other shipping ports along the coast that host several different types of national and international vessels and are connected directly to the Pacific Ocean (Table 1). The port of Manta is the largest seaport and the only deep-water port of Ecuador; it receives cargo ships, commercial fishing boats, artisanal fishing boats, private yachts, and cruise ships. Many international yachts make a stopover on the coast of Ecuador before travelling on to the Galapagos Islands. Manta receives 67% of this traffic, while the other 33% make their stopover in Guayaquil or Esmeraldas.

Fishing boats also travel from these ports to the GMR. However, fishing in the GMR is only permitted for vessels that are registered with the Galapagos National Park Directorate (GNPD) and follow the strict regulations that have been put in place. Fishing boats that travel from mainland Ecuador to the GMR to fish are conducting illegal activities, which are punishable by law.

<table>
<thead>
<tr>
<th>Port</th>
<th>Puerto de Esmeraldas</th>
<th>Puerto de Bahía de Caraquez</th>
<th>Puerto de Manta</th>
<th>Puerto de La Libertad / Salinas</th>
<th>Puerto Bolivar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of boat</td>
<td>Cargo</td>
<td>Private</td>
<td>Cargo</td>
<td>Oil</td>
<td>Cargo</td>
</tr>
<tr>
<td></td>
<td>Cruise</td>
<td>Fishing</td>
<td>Cruise</td>
<td>Fishing</td>
<td>Fishing</td>
</tr>
<tr>
<td></td>
<td>Fishing</td>
<td>Fishing</td>
<td>Fishing</td>
<td>Private</td>
<td>Cruise</td>
</tr>
</tbody>
</table>

**Table 1.** Main ports on the coast of Ecuador and the types of boats that go through the ports.

**Distribution of *Carijoa riisei* along the coast of Ecuador**

*Carijoa riisei* was first recorded in Ecuador in July 2010 by Odalisca Breedy, during the first octocoral survey conducted in the Machalilla National Park by scientists of the Nazca Institute for Marine Research (Martinez et al., 2011). This finding took place in the Salango Islet, and passed almost unnoticed (Martinez, pers. com.). Nevertheless, the following year (2011), a patch of *C. riisei* of about 4 x 6 m was found by Martinez in Piedra Quingue, Galera San Francisco Marine Reserve (Martinez, pers. com.). With this new finding, former black coral divers from the locality, who dove in the area between the 1980s and 1990s, were interviewed by the Nazca team to determine if *C. riisei* had been sighted in the past. The general response was that it is a new species in the reef.

Since then, *C. riisei* has continued expanding along the coast of Ecuador, competing with native fauna, monopolizing a variety of habitats, and affecting marine ecosystems in three provinces: Esmeraldas, Manabi, and Santa Elena, where most of the marine diversity of the country is concentrated. These provinces also include three Marine Protected Areas already invaded by *C. riisei*: Galera San Francisco Marine Reserve (GSFMR), Machalilla National Park (MNP), and El Pelado Marine Reserve (EPMR) (Figures 1; Table 2).

Starting from the north, in the GSFMR, *C. riisei* is becoming a dominant species at Piedra Quingue, with dense aggregations from 2–14 m depth. In this site, *C. riisei* has proven to grow well in both exposed and shaded areas (Figure 2). It is killing most of the sessile fauna, except for the ahermatypic coral *Tubastrea coccinea* that remains apparently unaffected (Figure 3). This response is consistent with that found in Gorgona Island, Colombia (Sánchez & Ballesteros, 2014). Other sites colonized by *C. riisei* in the GSFMR are Punta Alta, in the center of the Reserve, and continuing south from Tongorachi to Cape San Francisco, where instead of appearing in dense mats as in the previous sites, it is found spreading horizontally through its stolons or runners, over surfaces and small mounts.
Figure 1. Map of the coast of Ecuador. Red dots indicate the sites where *Carijoa riisei* has been observed.

Table 2. List of sites and GPS coordinates with records of *Carijoa riisei* along the coast of Ecuador. MPA = Marine Protected Area; GSFMR = Galera San Francisco Marine Reserve; MNP = Machalilla National Park, CMMR = Cantagallo Machalilla Marine Reserve and EPMR = El Pelado Marine Reserve.

<table>
<thead>
<tr>
<th>Province</th>
<th>MPA</th>
<th>Site</th>
<th>17M</th>
<th>UTM</th>
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</thead>
<tbody>
<tr>
<td>Esmeraldas</td>
<td>GSFMR</td>
<td>Piedra Quingue</td>
<td>0599247</td>
<td>0080437</td>
</tr>
<tr>
<td></td>
<td>GSFMR</td>
<td>Punta Alta</td>
<td>0600449</td>
<td>0072397</td>
</tr>
<tr>
<td></td>
<td>GSFMR</td>
<td>Tongorachi</td>
<td>0600326</td>
<td>0072922</td>
</tr>
<tr>
<td></td>
<td>Non-protected</td>
<td>Mompiche</td>
<td>0605811</td>
<td>0054567</td>
</tr>
<tr>
<td></td>
<td>Non-protected</td>
<td>Bajo Londres</td>
<td>0574562</td>
<td>9980706</td>
</tr>
<tr>
<td>Manabí</td>
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<td>Vaca Brava</td>
<td>0567415</td>
<td>9973393</td>
</tr>
<tr>
<td></td>
<td>Non-protected</td>
<td>Cabo Pasado</td>
<td>0557298</td>
<td>9960474</td>
</tr>
<tr>
<td></td>
<td>MNP</td>
<td>Sombrerito</td>
<td>0525520</td>
<td>9844648</td>
</tr>
<tr>
<td></td>
<td>MNP</td>
<td>Horno de Pan</td>
<td>0521245</td>
<td>9834355</td>
</tr>
<tr>
<td></td>
<td>MNP</td>
<td>Salango W</td>
<td>0513926</td>
<td>9823793</td>
</tr>
<tr>
<td></td>
<td>CMMR</td>
<td>Los Ahorcados</td>
<td>0518396</td>
<td>9814566</td>
</tr>
<tr>
<td>Santa Elena</td>
<td>Non-protected</td>
<td>Bajo Cope</td>
<td>0492958</td>
<td>9799684</td>
</tr>
<tr>
<td></td>
<td>EPMR</td>
<td>Bajo 40</td>
<td>0523735</td>
<td>9785783</td>
</tr>
<tr>
<td></td>
<td>EPMR</td>
<td>La Pared</td>
<td>0523085</td>
<td>9786376</td>
</tr>
</tbody>
</table>
In Manabí, *Carijoa riisei* was observed off the coast near Jama, in Bajo Londres and Vaca Brava. These two sites presented low diversity and high levels of sediment, but *C. riisei* seemed to tolerate the conditions as they did at Cabo Pasado, where the bottom is covered with sediment from nearby rivers and *Carijoa* is very conspicuous (Figure 4).
South of Manabí, *Carijoa riisei* is found around the islets at Machalilla National Park: Salango, Sombrerito, and Horno de Pan. Next to MNP, at the Cantagallo Machalilla Marine Reserve in the islet Los Ahorcados, one of the most diverse places for octocorals along the coast of Ecuador, *C. riisei* has expanded from a colony of less than 30 x 40 cm photographed by F. Rivera in 2009, to an aggregation of about 350 x 400 cm in 2015 (Figure 5).

![Figure 5. Comparison of 30 x 40 cm colony of *Carijoa riisei* in 2009 (left) and its expansion to a patch of 350 x 400 cm in 2015 (right).](image)

In the Santa Elena Province, *C. riisei* was found in Bajo Cope and in El Pelado Marine Reserve, a tourist dive site, where it has become notorious at the dive sites La Pared and Bajos (Cuarenta, Ignacio, and Portete) (F Rivera & J Feijó, pers. com., 2014-2015).

The spread of *C. riisei* in all these sites is accompanied by habitat alteration and local decline in diversity and species richness (Cárdenas et al., 2016). Its aggressive behavior, displacing native species, turns the areas where it settles into dense monospecific mats (Martinez, pers. com.).

**Threat of *Carijoa riisei* reaching the GMR**

The establishment of *C. riisei* along the coast of mainland Ecuador represents a continuous threat to the marine environments of the Galapagos Islands. According to the International Union for Conservation of Nature (IUCN), this octocoral is one the worst invasive marine species; it has caused serious impacts to the ecosystems and economy of Hawaii, affecting the black corals (Kahng & Grigg, 2005). This is a risk for Galapagos, where black corals are important components of the reef communities, widely distributed in all the islands (Wellington, 1975) and indicators of the marine composition and function (Branch et al., 2002).

The potential of transferring *C. riisei* to Galapagos via hull biofouling from mainland Ecuador, whether by recreational sailboats, illegal fishing boats, or Navy vessels, is high. *C. riisei* is a common fouling organism found on ship bottoms, buoys, and wharves (De Felice et al., 2001). This fact, coupled with its rapid expansion along the mainland coast and with the increased frequency of vessels travelling from mainland Ecuador to Galapagos, raises the threat of it reaching the islands. On the other hand, larval dispersal does not seem to be a risk factor; reproductive studies of *C. riisei* in Hawaii indicate that it has a negatively buoyant larva (Kahn et al., 2008), with low dispersal capacity (Concepcion et al., 2010).

**Discussion**

The presence of *Carijoa riisei* along the coast of Ecuador and its rapid expansion during recent years reveals the potential for further invasions and increases the risk of its dispersal to Galapagos. In addition, the intensification of marine traffic from mainland Ecuador to the Archipelago increases the risk of *C. riisei* being transported to the GMR. This invasive species displaces native fauna and adapts well to different environments. In Hawaii, *C. riisei* is more restricted to cryptic habitats and turbid waters, avoiding direct sunlight (Kahng & Grigg, 2005). Whereas in Ecuador, it tolerates a wide range of habitats and conditions: shaded ledges with direct light and high current flow, rocky walls, complex boulders, as well as flat surfaces. It grows on bare rock, coralline calcareous algae, and on substrates covered with sediment. This remarkable plasticity of adaptations, together with its competent reproductive strategies (Kahng et al., 2008), have contributed to its successful establishment and expansion along the coast of mainland Ecuador.

**Recommendations**

Given the importance of ensuring that *C. riisei* does not arrive in Galapagos or become established if it does arrive, we recommend the following actions:
• The authorities of Ecuador should maintain the prohibition for international cruise line ships to enter the Galapagos Islands.

• All vessels visiting the islands must clean their hulls before their arrival to avoid the introduction of invasive species attached as fouling. Currently, the Galapagos Biosecurity Agency (ABG – Spanish acronym) officials require international vessels arriving in Galapagos to show proof of the hull being cleaned in the last port of call.

• The marine monitoring program must be continued and expanded throughout the Islands, with an emphasis in regular surveys of the main ports for early detection, rapid response, and prevention of the spread of alien species.

• Galapagos divers, fishermen, and naturalist guides should be taught to recognize C. riisei and then inform GNPD and ABG authorities, or Charles Darwin Foundation scientists, if sighted in the GMR.

• A molecular genetic analysis of C. riisei colonies from mainland Ecuador should be completed to determine if their origin is from the Caribbean or Indo Pacific. Knowing the origin can help managers identify introduction pathways, and alert them to potential risks posed by vessels arriving from that particular area.

Acknowledgments

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GALAPAGOS REPORT 2015-2016

MARINE MANAGEMENT

REPORT ON THE POPULATION STATUS OF HAMMERHEAD SHARKS IN THE GALAPAGOS MARINE RESERVE

César Peñaherrera-Palma, Eduardo Espinosa, Alex R. Hearn, James Ketchum, Jayson M Semmens and Pete Klimley

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Report on the population status of hammerhead sharks in the Galapagos Marine Reserve

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The hammerhead shark (Sphyrna lewini) is in danger of extinction throughout its worldwide distribution, primarily due to overfishing (Baum et al., 2007). Several studies have reported population reductions of up to a 90% (e.g., Baum & Myers, 2004; Ferretti et al., 2008) in areas within the marine protected areas of the Eastern Tropical Pacific (ETP). On Cocos Island, ~700 km from the Galapagos Marine Reserve (GMR), this species’ abundance has declined by 50% since the 1990s (White et al., 2015). Similarly, in Malpelo Island, ~1000 km from the GMR, hammerhead sharks have declined by 45% since the beginning of the 2000s (Soler et al., 2013).

The gregarious behavior and singular body form of this species have transformed it into one of the most important marine tourist attractions in the GMR (Danulat et al., 2003). It is one of the dominant reasons that Galapagos is listed as one of the best dive destinations in the world (Scuba-Diving, 2000; 2008; 2012). This species is distributed throughout the Archipelago, but can be observed in higher numbers at Wolf and Darwin Islands, especially during the cold season (Hearn et al., 2014). Despite the economic importance of this species for both tourism and commerce in Galapagos (Peñaherrera et al., 2013), little is known about its population status and its use of the GMR (Hearn et al., 2014). This document supports the recently adopted zoning system by summarizing published information and expanding that knowledge with new details about the population status of hammerhead sharks.

Methods

This study employed several analytical tools used in social sciences, population ecology, and behavioral ecology. For example, to understand how hammerhead sharks use the GMR, we studied their migratory behavior and site fidelity using acoustic and satellite telemetry (methodology described in Hearn et al., 2014). Telemetry provides remote tracking of animals to determine their presence, position, or physiological state (Cooke et al., 2004), and was used to estimate probable range (Bullard, 1999). Due to a lack of information, the historical population trend was assessed using a semi-quantitative tool that models virtual abundance change (VAC) based on local ecological knowledge (methodology described in Peñaherrera et al., 2015). Relative abundance (total number of sharks observed during a one-hour dive) has been measured since 2007. This is done by
visual censuses during autonomous dives in several dive sites of the GMR (methodology described in Hearn et al., 2014). Finally, population size of hammerhead sharks at Darwin Island was estimated using a combination of visual counts with acoustic telemetry (methodology described in Peñaherrera-Palma, 2016). Unlike other underwater census methodologies (such as visual censuses or stereo-cameras), assessment of population size provides information on the number of unique individuals that exist in an area. This in turn makes it possible to determine with greater certainty the number of individuals that can co-exist in the same place during a defined period of time and thus calculate the true existing biomass with greater accuracy.

**Use of the GMR**

Studies carried out since 2006 show that hammerhead sharks have a high preference for the areas around Darwin and Wolf Islands, and on a smaller scale around Roca Redonda (Ketchum et al., 2014b). Although sharks have been marked in the northern and central-southern regions of the GMR, only one shark was observed migrating from the north to the south, and another from south to north (Ketchum, 2011). This has raised doubts about the connectivity and use of the two regions for this species. Hearn et al. (2014) suggested the existence of possible differences in the use of the GMR depending on whether individuals are adult or juvenile. His hypothesis is based on two points: 1) the differences in the average size of the individuals marked in the north (181 +/-24 cm) and those marked in the south (141 +/-11 cm); and 2) records of juvenile hammerhead sharks in some breeding areas of blacktip reef sharks (Llerena, 2009; Jaenig, 2010). Although data are not yet sufficient to verify this hypothesis (for example, breeding areas not yet identified), studies in the Ecuadorian oceanic territory have shown that there are differences in the type of food consumed by adult and juvenile hammerhead sharks (Loor-Andrade et al., 2015).

Ketchum et al. (2014a) determined that during the day, hammerhead sharks use areas of strong currents around Darwin and Wolf, possibly as resting zones. During the night they move a considerable distance away from the islands, potentially towards feeding areas in open water. The extent of hammerhead shark movements in open water is greatly influenced by oceanographic conditions (Peñaherrera-Palma, 2016). For example, during the cold season (June-October), 90% of the area used by hammerhead sharks fell within the GMR, though most was concentrated around Darwin and Wolf. However, the amount of time spent in the GMR during the transition months was reduced to 65%, and to only 30% during the warm season (Figure 1). These movements differ considerably with other shark species, such as the blacktip reef shark (Peñaherrera-Palma, 2016) and the Galapagos shark (Hearn et al., 2014), whose movements are restricted primarily to coastal areas within the limits of the GMR.

**Population trends**

The population analysis using the VAC model shows a perceived reduction of 50% in hammerhead shark abundance since the 1980s (Peñaherrera-Palma et al., 2015; Figure 2). These data suggest that in the early 1980s a diver could observe on average ~100 hammerhead sharks per dive throughout the GMR. From 2010 to 2013, the average relative abundance was 50.6 ind/dive-hour (Peñaherrera-Palma, 2016). The greatest reduction in the abundance of this species was perceived in the central and southern areas of the Archipelago. Divers also indicated that in the past, the southern-central regions of the GMR had significant aggregations of hammerhead sharks, in numbers close to those seen today at Darwin and Wolf (Peñaherrera-Palma et al., 2015). Although it is unknown what the relative abundance of hammerhead sharks was in the central and southern areas of the Archipelago prior

![Figure 1. Spatial and temporal use of the GMR and surrounding waters by eight hammerhead sharks tracked with satellite telemetry. Cold refers to the months of the cold season (June-October); Hot, the hot season (December-April); and Transition, the months between the two seasons (May and November). Orange indicates 95% probability distribution; Red indicates 50% probability distribution. Source: Peñaherrera-Palma (2016)](image-url)
to 1980, current visual census data indicate an annual average of 25 ind/dive-hour.

In Darwin and Wolf the annual average has been recorded up to 128 ind/dive-hour, indicating that these are the only sites in the GMR where you can still see hammerhead sharks in large numbers. However, since 2007, the areas around these islands show a negative trend in the relative abundance of this species. Trends in the rest of the GMR show an apparent increase, although the magnitude represents less than a quarter of what is observed in Darwin and Wolf.

**Population size**

Despite the abundance of individuals seen at Darwin and Wolf, the study of the size of the resident population at Darwin Island suggests that there are limitations to the number of unique individuals that can frequent the island at the same time (Peñaherrera-Palma, 2016). This analysis estimated that the average size of the resident population of hammerhead sharks fluctuates between 400 to 600 individuals (Figure 3). These results suggest that Darwin, and quite possibly Wolf, could represent areas with a limited carrying capacity in terms of the abundance of unique individuals of hammerhead sharks. This is of great interest for conservation, as at Darwin the resident population consists of individuals with an average total length of 238 cm, with a majority of females (85-90%; Peñaherrera-Palma, 2016; Figure 3).
Conclusions and recommendations

This research highlights the following points:

1. The susceptibility of this species when it migrates out of the GMR, especially during the hot season. Although sharks are protected within the GMR by the current management framework, we recommend expanding conservation efforts to improve fishing regulations outside the GMR. This could help: 1) reduce the susceptibility of this species to both national and international fishing fleets in open water; and 2) slow down the population decline observed in the north of the GMR. All research and management efforts should be coordinated with neighboring countries that share the stock of hammerhead sharks in the Eastern Tropical Pacific, such as Colombia, Costa Rica, and Panama.

2. The possible existence of breeding areas of this species in the south-central region of the GMR and the connection with areas of aggregation in the north. It is critical to assess the existence of these breeding areas to understand the role of the GMR in the protection of other key life stages of hammerhead sharks.

3. The apparent increase in the relative abundance of hammerhead sharks in some historical aggregation sites (e.g., Floreana, North Seymour, Genovesa, Marchena). We recommend a more detailed evaluation of the causes that generated the decline in abundance, as well as the biological and management factors that could optimize the increase in abundance in these areas. The recovery of these aggregation sites will: 1) improve the conservation status of this species in danger of extinction; 2) provide new dive sites with characteristics similar to Darwin and Wolf; and 3) reduce the intensity of use of the dive sites at Darwin and Wolf Islands.

4. The possible existence of a limit on the number of sharks that can co-habit the areas around Darwin and (potentially) Wolf. We need to evaluate in greater detail what factors limit the presence of hammerhead sharks at these aggregation sites. Determining these factors is critical to: 1) ensure habitat quality for resting and for aggregations of hammerhead sharks in the north of the GMR; 2) provide conservation indicators to assess historical aggregation areas; and 3) promote the recovery of hammerhead sharks to historical levels in the central-southern areas of the GMR.

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GALAPAGOS REPORT 2015-2016

MARINE MANAGEMENT

TEN YEARS OF TRACKING SHARK MOVEMENTS HIGHLIGHT THE ECOLOGICAL IMPORTANCE OF THE NORTHERN ISLANDS: DARWIN AND WOLF

Alex Hearn, Eduardo Espinoza, James Ketchum, Jonathan Green, César Peñaherrera, Randall Arauz, Chris Fischer, Todd Steiner, George Shillinger, Scott Henderson, Sandra Bessudo, German Soler and A. Peter Klimley

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The Galapagos National Park Directorate has its headquarters in Puerto Ayora, Santa Cruz Island, Galapagos and is the Ecuadorian governmental institution responsible for the administration and management of the protected areas of Galapagos.

The Governing Council of Galapagos has its headquarters in Puerto Baquerizo Moreno, San Cristóbal Island, and is the Ecuadorian governmental institution responsible for planning and the administration of the province.

The Charles Darwin Foundation, an international non-profit organization registered in Belgium, operates the Charles Darwin Research Station in Puerto Ayora, Santa Cruz Island, Galapagos.

Galapagos Conservancy, based in Fairfax, Virginia USA, is the only US non-profit organization focused exclusively on the long-term protection of the Galapagos Archipelago.
Ten years of tracking shark movements highlight the ecological importance of the northern islands: Darwin and Wolf

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6University of Tasmania 7PRETOMA, 8Ocearch
9Leatherback Trust 10Conservation International
11Fundación Malpelo 12University of California Davis

Introduction

The Galapagos Marine Reserve (GMR) was created to provide protection to the native and endemic species that inhabit the islands and their surrounding waters. However, on a region-wide scale it also provides partial protection for marine migratory species that move through its waters at certain life stages or times of year. Among these species, sharks are of particular interest, as they often occupy top predator ecological niches and may act as agents of natural selection. They are also highly vulnerable due to their slow growth, late onset of maturity, low reproduction rate, and low natural mortality (Myers & Worm, 2005). With increasing demand for shark fins over the last two decades, many shark populations around the world are declining (Dulvy et al., 2014). Finally, they contribute directly to many economies, including Galapagos, through recreational dive tourism.

In 2006, we began a long-term research program to understand how sharks utilize the GMR and established links with colleagues in other oceanic islands in the Eastern Tropical Pacific (ETP) doing simultaneous studies with compatible technologies. This led to the creation of the regional MigraMar network later that year; its mission is to conduct scientific research to better understand and safeguard healthy populations of marine migratory species in the ETP. Our efforts in the GMR focused on the northern islands of Darwin and Wolf. There, huge schools of scalloped hammerhead sharks (Peñaherrera et al., 2017) mingle with Galapagos and blacktip sharks in deep water just off the shallow reefs (Figure 1). Silky sharks patrol the open waters, while from June through late November, a steady stream of large female whale sharks move past the islands on their ocean-wide migration. These two islands have become a beacon for recreational divers from all over the world. But why are these islands so special? What are the driving forces that place them among the most biologically spectacular sites on the planet?
Methods

We deployed an array of underwater receivers around Darwin and Wolf, and at other locations in the GMR, such as Roca Redonda, Gordon Rocks, and Cousins. Similar arrays were deployed throughout the region by the MigraMar network (Figure 2). These receivers detect and record data sent from ultrasonic tags placed on over 1000 sharks and other species, allowing us to analyze their residency at each island, their site fidelity, and inter-island movements.
Ultrasonic tags, small devices that emit signals at a high frequency, each with a ten-year battery, were attached by free diving into the schools of sharks then using pole spears to dart the sharks (Figure 3a). We also surgically implanted tags, which requires capturing the sharks. Each tag is recorded with a time stamp when in range (approximately 200 m) of any receiver.

SPOT tags (Figure 3b) send information to a network of satellites, which is then relayed to the scientists. They send a position whenever the tag is at the surface, either because it is towed on a cable behind the shark, or attached to the fin (some sharks, hammerheads included, swim with their fins above the surface at certain times of day). This allows us to create tracks of where the sharks are.

Over the ten-year study, we placed ultrasonic tags in over 200 hammerhead sharks at Darwin and Wolf, and 36 on a combination of Galapagos, silky, blacktip, and whale sharks (Table 1). Satellite tags were used to track eight hammerheads, five blacktips, three Galapagos, 11 silky, and 45 whale sharks as they move between and around Darwin and Wolf.

Table 1. Satellite (S) and Acoustic (A) tags placed on five species of shark at Darwin, Wolf, central Galapagos, and the Eastern Tropical Pacific.

<table>
<thead>
<tr>
<th>Species</th>
<th>Darwin</th>
<th>Wolf</th>
<th>Central Galapagos</th>
<th>Rest of MigraMar Network</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Tag Type</td>
<td>A</td>
<td>S</td>
<td>A</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Hammerhead shark</td>
<td>115</td>
<td>2</td>
<td>91</td>
<td>8</td>
<td>494</td>
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<tr>
<td>Galapagos shark</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>101</td>
</tr>
<tr>
<td>Silky shark</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>82</td>
</tr>
<tr>
<td>Blacktip shark</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td>Whale shark</td>
<td>5</td>
<td>66</td>
<td>2</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>81</td>
<td>112</td>
<td>20</td>
<td>740</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>168</td>
</tr>
</tbody>
</table>

Results

Despite differences in their ecology, all species except whale sharks share common patterns:
- High degree of site fidelity at both islands
- High degree of site specificity at current-facing “hotspots”
- Frequent movements between both islands
- Some movements to and from other marine reserves

Hammerhead sharks aggregate close to the current-facing sides of both islands (Figure 4). These “hotspot” areas (Hearn et al., 2010) of activity are less than 0.5 km² (Ketchum et al. 2014a). During daylight hours they can be observed singly or in small groups on the reef, where they may interact with cleaner fish¹, or in large schools circling around the hotspot area further offshore. At dusk, the sharks disperse, often moving several kilometers in a straight line away from the island, then randomly over a

¹ Some sharks will move slowly over areas of reef, allowing certain reef fish, such as king angelfish and barberfish, to approach them to remove parasites and dead skin. The areas where these interactions occur persistently are commonly known as “cleaning stations.”
From March through June, the hammerheads are less abundant at the islands. During this period, we have detected our sharks at Cocos Island, 690 km away (Ketchum et al., 2014b). We suspect that these movements are fairly directional, probably along the Cocos Ridge, which links Cocos and Galapagos. Cocos Island may not be their destination, rather they may continue to the coastal bays of Central America, where neonate hammerheads appear around this time of year. Determining any connection between adult aggregations at Darwin and Wolf, and juvenile nursery grounds along the coast remains one of our goals.

Two blacktip sharks tagged at Darwin remained close to the island for one and two months respectively, before moving to Wolf for a short period (Figure 5). At both islands, they were detected intermittently and mostly during daytime hours. A third blacktip was briefly detected at Gordon Rocks in the central archipelago, then vanished for two years, before spending the next two years moving around the central islands.

Silky sharks, generally considered nomadic ocean wanderers, showed extremely high site fidelity, largely remaining at the island where they were tagged for extended periods, with brief visits to the other island (Figure 5).

Galapagos sharks displayed a more varied behavior; nearly all moved between Darwin and Wolf at least once, and while at an island, tended to remain close to the reef. However, they also spent extended periods offshore (Figure 5).
Figure 5. Residency and movements of blacktip, silky, and Galapagos sharks tagged at Darwin and Wolf.

Figure 6. Map of habitat use polygons for sharks tagged with satellite positioning devices at Darwin and Wolf.
The Equatorial Front is also the destination of a steady trickle of whale sharks that move past Darwin each year (Figure 7). Unlike the other sharks, whale sharks are not residents in Galapagos (Acuña et al., 2014). The whale shark is the world’s largest fish, some over 15 m. Although mostly solitary, around a dozen aggregation sites are known worldwide, made up mostly of immature (< 7 m) males feeding on seasonal plankton blooms. Most whale sharks at Darwin are female, larger than 10 m; they are not feeding and most appear pregnant (Hearn et al., 2013). Early in the cool season (July), they move westwards offshore to the Equatorial Front, when it is at its most productive (Figure 7). By September they start returning eastwards, often close to Darwin, but continue to the continental shelf off the coast of Ecuador and Peru (Hearn et al., 2016), which is also seasonally at its most productive. Reports from Galapagos guides, local fishers, and industrial fishing observers suggest that from March through June they can be seen to the southwest of Isabela.

![Figure 7. Whale sharks tracked from Darwin move west into the open ocean, returning through Galapagos later in the year, on their way to the continental shelf of Ecuador and Peru.](image)

**Discussion**

While the open ocean can seem a featureless environment, oceanic islets provide structural complexity to both ocean bathymetry and current patterns. Persistent wake structures are present at oceanic islets where there is a strong mean flow of currents. Bow wave effects are produced on the upstream coast of islets, where the current stalls as it splits to flow around the islet, forming an entrapment area (Figure 8), where plankton can accumulate, forming the basis of an enhanced food chain. The Arch at Darwin and Shark Point at Wolf are classical examples. These “hotspots” are the epicenters of life at each island. Planktivorous fishes on the upstream reef face form a “wall of mouths” that feeds on the plankton as it arrives. This phenomenon is commonly seen at Darwin, where the entire reef face is covered with a living wall of Pacific creolefish, facing out into the current and feeding on the material brought to the island from offshore.

Another explanation for some aggregations is that islands serve as landmarks. Providing a perceptible physical property, such as the local magnetic field intensity, these landmarks could be used for guidance during daily and seasonal migrations. We have observed two apex predators, bottlenose dolphins and Galapagos sharks, feeding at the hotspot at Wolf. However, scalloped hammerhead sharks have never been observed to feed during the day close to shore, yet they have been tracked away from the island at nighttime. They likely forage at this time and return to the hotspot at dawn.

Darwin and Wolf also provide other services. Hammerheads spend a significant portion of their time at the reef being
cleaned by small reef fish. The islets also provide a fixed point where important social activity takes place. The complex behavior of the large schools of hammerheads is poorly understood, but schools are made up mainly of females, the largest jostling for position in the center, while occasional males move around the outside (Klimley & Nelson, 1984).

In the case of whale sharks, why would large, apparently pregnant females go past Darwin each year, without feeding or stopping? The answer may be complex. These females seem to be making seasonal movements between three foraging grounds separated by many hundreds of kilometers. Darwin is likely a navigational waypoint, allowing them to get from one site to the next. But why almost exclusively adult females? It could be that they are on their way to pupping grounds. Three neonate whale sharks were caught in deep water, far to the north of Galapagos many years ago. To date, only a handful of neonates have ever been found globally, and no whale shark nursery grounds have ever been identified. Maybe whale sharks give birth out in the open ocean over a large area and time period, perhaps along the Equatorial Front. This would explain why the embryos in the only pregnant female ever to be examined were all at different stages of development (Schmidt et al., 2010).

Why are Darwin and Wolf so special if many oceanic islets share similar characteristics? Firstly, they are incredibly remote, and have been subjected to less fishing pressure than their coastal counterparts. Truly oceanic, not part of the Galapagos platform, they provide an interface between shallow reef and very deep water. Thirdly, their position just to the south of the Equatorial Front suggests that they may be a strategic location for navigation between areas of high seasonal productivity. Finally, as part of the GMR, they have been protected from industrial fishing since 1998.

Malpelo (Colombia) and Cocos (Costa Rica), other islands in the region, share an extraordinary abundance of sharks and other top predators. Along with Galapagos and the coastal island of Coiba (Panama), they are all UNESCO Marine World Heritage Sites. In 2004, the Governments of Ecuador, Colombia, Costa Rica, and Panama created the Eastern Tropical Pacific Seascape (ETPS), encompassing the entire Exclusive Economic Zones (EEZs) of all four nations, setting the four UNESCO sites within a protective envelope of over two million hectares, where sustainable economic use and conservation of threatened species were to be promoted.

Despite sharks being legally protected at all these locations, threats remain from industrial fishing vessels making illegal incursions into the reserves and from fishing when the sharks move outside reserve boundaries. In Galapagos, there have been cases of shark-finning by some local fishers. There has also been intense pressure to allow local fishers to use longlines. Several experimental fisheries over the last fifteen years have shown this to have unacceptably high by-catch of sharks (e.g., Murillo et al., 2003). It is not uncommon for divers to encounter sharks with hooks in their mouths at Darwin or Wolf (Figure 9).

**New zonation scheme**

A new zonation of the GMR was approved in early 2016, a component of which was the creation of a large no-take zone encompassing all the GMR waters north of 0.7°N, thus removing all fishing pressure around Darwin and Wolf (Ministerial Decree 026-A, 23 March 2016).
movements of sharks between the islands suggests that managing them as a single unit is appropriate. The intense use by sharks of the open ocean around Darwin and Wolf are clear indications that the original coastal zonation was inadequate. However, it must not be forgotten that sharks have been protected in the entire GMR since 1998, that there was little risk of shark mortality from artisanal lobster and hand-line fishing, and that any direct threats by illegal fishing, both local and industrial, remain an issue of enforcement. The islands provide key services to the sharks and to other open water species and eliminating fishing pressure on lobsters, groupers, and other reef fish around the islands will promote a healthy reef, which will maintain important cleaning stations and prey items for top predators. It will be crucial in the coming months to work closely with the artisanal fishing sector so that they can share in the benefits that investing in such a large no-take area will generate for the Galapagos economy.

**Next steps for conservation**

As members of the Migramar network, our results are used to provide technical advice on the design and management of marine protected areas, and on the adoption of national and international legislation to protect sharks.

We are currently supporting the inclusion of silky sharks in CITES – an international treaty that regulates wildlife trade. After the successful inclusion of hammerheads in 2014, the situation of the silky shark is of highest priority. Silky sharks are commonly found associated with schools of tuna and are highly vulnerable to the industrial purse seine fishery, as well as the semi-industrial and artisanal longline fleets. Three of our tagged silkies were caught and landed by fishers (one within the GMR).

Conservation efforts within the GMR and the other regional Marine Protected Areas must focus on improving enforcement. The seasonal presence of different shark species at these hotspots should be used to design efficient and effective patrolling and enforcement strategies, and to create a tiered approach to tour operation patents to finance the former.

Our results show that sharks frequently move beyond the boundaries of protected waters. In the case of hammerhead sharks, there is an area of seamounts only 100-150 km northwest of Darwin where several individuals have been tracked. This area should be explored for potential expansion of the GMR following in the footsteps of Cocos, Coiba, and Malpelo reserves, all of which have been recently expanded.

Other hammerhead movements are associated with the Cocos Ridge. In 2012, Cocos Island Marine Reserve was extended to protect an area of seamounts to the southwest of the island. This was a first step in the direction from Cocos to Galapagos along the Cocos Ridge. Our studies have shown that silky and Galapagos sharks may also navigate along this ridge when moving between the islands. Green turtles also use the ridge, and endangered leatherback turtles migrate through here from their nesting beaches in Costa Rica.

Although the entire area of ocean between Darwin/Wolf and Cocos is under the jurisdiction of either Costa Rica or Ecuador, once sharks, turtles, and other marine megafauna leave the marine reserves, they are vulnerable to intense fishing, and not all by vessels authorized to be there. As both Ecuador and Costa Rica move forward...
in protecting their resources and natural heritage, we envision a bilateral “Swimway” spanning the two reserves (Figure 10), where both nations exercise their sovereignty to eliminate illegal, unreported, and unregulated fisheries, use their resources sustainably, and continue to increase protection for threatened migratory marine species.

In 2016 we received funding from the Leona M. and Harry B. Helmsley Charitable Trust to organize and strengthen our regional MigraMar network. This will allow us to continue relevant research on migratory marine species, reinforce our collaboration on a regional scale, and provide technical conservation advice to both national and international decision-making bodies.

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Figure 10. Proposed “Swimway” along the Cocos Ridge.
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