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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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*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.*

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

César Peñaherrera-Palma[1,2,3], Eduardo Espinoza[3], Alex R. Hearn[4,5], James Ketchum[6], Jayson M. Semmens[1] and Pete Klimley[7]

[1]Institute of Marine and Antarctic Studies, University of Tasmania, Australia
[2]CSIRO Marine and Atmospheric Research, Australia
[3]Galapagos National Park Directorate
[4]GAIAS – Universidad San Francisco de Quito, Galapagos
[5]Turtle Island Restoration Network, California, USA
[6]Pelagios Kakunjá, La Paz, Baja California, Mexico
[7]University of California, Davis

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.

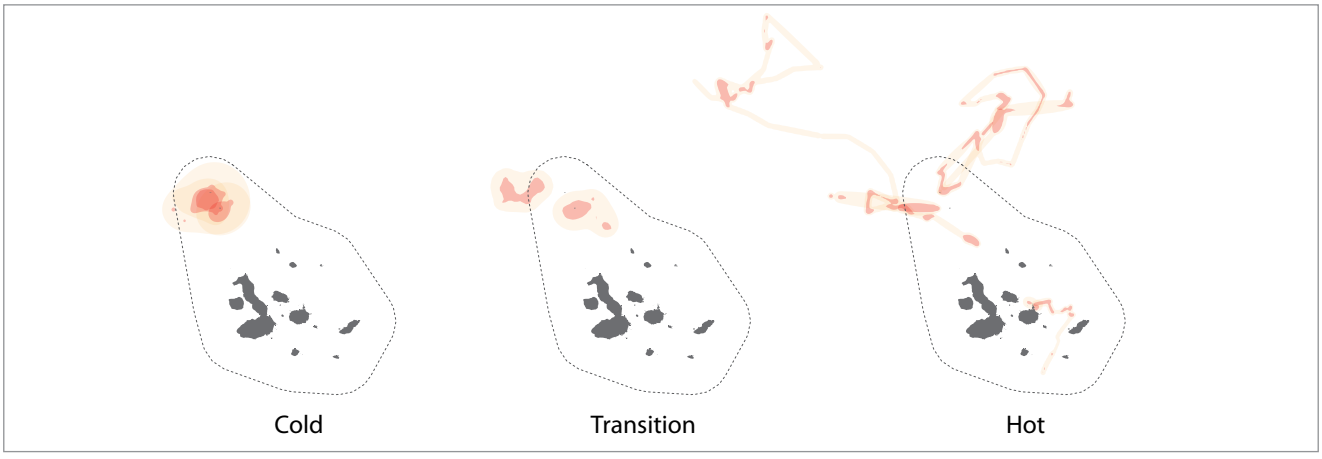

Figure 1. Spatial and temporal use of the GMR and surrounding waters by eight hammerhead sharks tracked with satellite telemetry. Cold refers to the months of the cold season (June-October); Hot, the hot season (December-April); and Transition, the months between the two seasons (May and November). Orange indicates 95% probability distribution; Red indicates 50% probability distribution. Source: Peñaherrera-Palma (2016)

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

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.

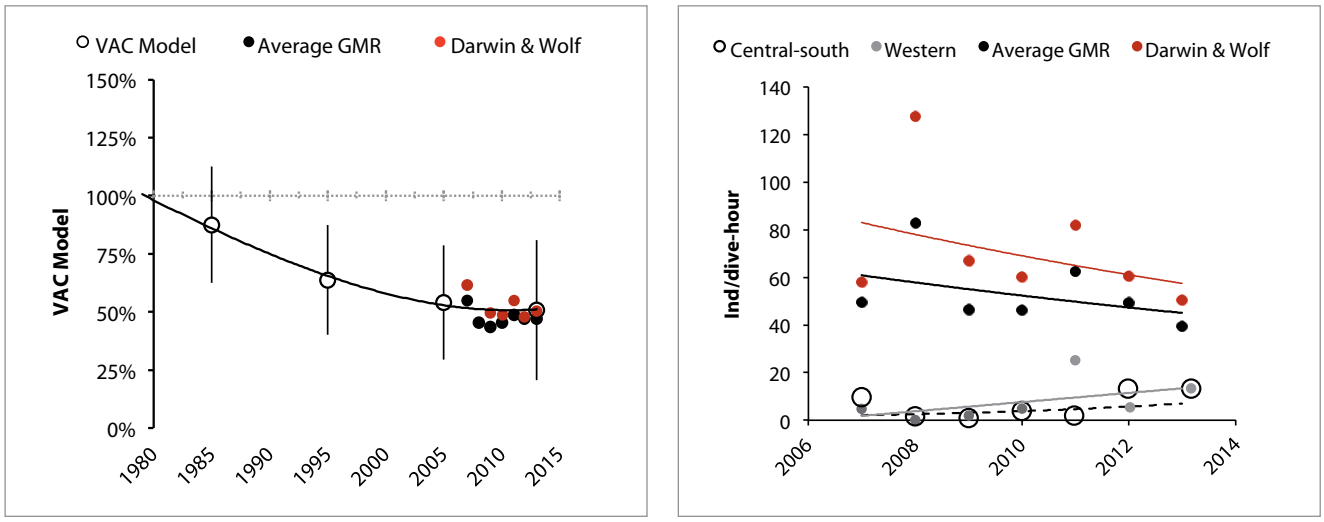

Figure 2. Overlaying the virtual abundance change (VAC) with the average annual relative abundance of hammerhead sharks around Darwin and Wolf, and throughout the GMR (left). Comparison of the relative abundance of hammerhead sharks between the south-central and western (Roca Redonda) bio-regions, with the global average of Darwin and Wolf and the GMR (right). Source: Peñaherrera-Palma (2016)

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).

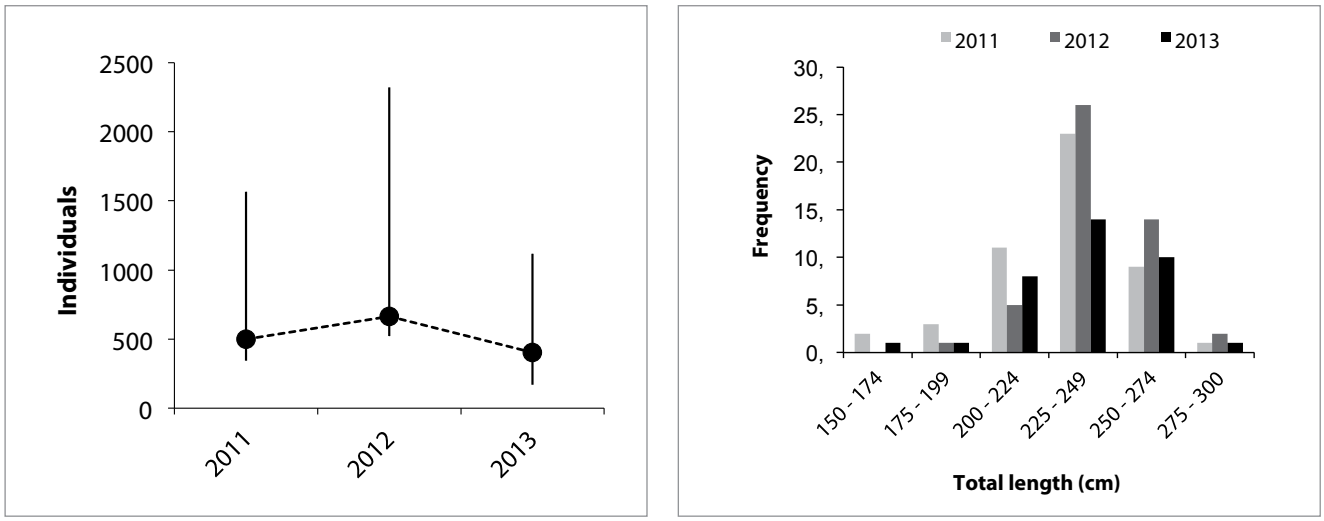

Figure 3. Estimates of population size of the resident population (left) and frequency of sizes measured with photogrammetry laser (right) of hammerhead sharks at Darwin's Arch. Source: Peñaherrera-Palma (2016)

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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References

Baum J, S Clarke, A Domingo, M Ducrocq, AF Lamónaca, N Gaibor, R Graham, S Jorgensen, JE Kotas, E Medina, J Martinez-Ortiz, J Monzini Taccone di Sitizano, MR Morales, SS Navarro, JC Pérez-Jiménez, C Ruiz, W Smith, SV Valenti & CM Vooren. 2007. *Sphyrna lewini*. International Union for the Conservation of Nature. 2.

Baum JK & RA Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7(2):135-145.

Bullard F. 1999. Estimating the home range of an animal: a Brownian bridge approach. Master thesis. Johns Hopkins University.

Cooke SJ, SG Hinch, M Wikelski, RD Andrews, LJ Kuchel, TG Wolcott & PJ Butler. 2004. Biotelemetry: a mechanistic approach to ecology. Trends in Ecology and Evolution 19(6):334-43.

Danulat E, M Brandt, P Zárate, M Montesinos & S Banks. 2003. El turismo en la Reserva Marina de Galápagos. Análisis global y condiciones en sitios de visita marinos seleccionados. Estación Científica Charles Darwin y Dirección Parque Nacional Galápagos. Puerto Ayora, Galapagos, Ecuador.

Ferretti F, RA Myers, F Serena & HK Lotze. 2008. Loss of large predatory sharks from the Mediterranean Sea. Conservation Biology 22(4):952-64.

Hearn AR, D Acuña, JT Ketchum, C Peñaherrera, J Green, A Marshall, M Guerrero & G Shillinger. 2014. Elasmobranchs of the Galapagos Marine Reserve. *In* Galapagos Marine Reserve: a dynamic socio-ecological system. Pp. 23-59. Denkinger J & L Vinueza.

Jaenig M. 2010. Sharks (Selachii) in mangrove-fringed habitats of the Galápagos Marine Reserve (GMR) with implications for management and conservation. Master in Science. University of Bremen. Bremen, Germany.

Ketchum J. 2011. Movement patterns and habitat use of scalloped hammerhead sharks (*Sphyrna lewini*) in the Galapagos Islands: Implications for the design of marine reserves. PhD dissertation. University of California - Davis. Davis, California, USA.

Ketchum JT, A Hearn, AP Klimley, E Espinoza, C Peñaherrera & JL Largier. 2014a. Seasonal changes in movements and habitat preferences of the scalloped hammerhead shark (*Sphyrna lewini*) while refuging near an oceanic island. Marine Biology 161(4):755-767.

Ketchum JT, A Hearn, AP Klimley, C Peñaherrera, E Espinoza, S Bessudo, G Soler & R Arauz. 2014b. Inter-island movements of scalloped hammerhead sharks (*Sphyrna lewini*) and seasonal connectivity in a marine protected area of the eastern tropical Pacific. Marine Biology. 10.1007/s00227-014-2393-y

Llerena Y. 2009. Identificación de tiburones juveniles y caracterización de sus hábitats en las zonas costeras de pesca de la isla San Cristóbal - Reserva Marina de Galápagos. Tesis de grado presentada como requisito para la obtención del título de Bióloga. Universidad de Guayaquil. Guayaquil, Ecuador.

Loor-Andrade P, F Galván-Magaña, FR Elorriaga-Verplancken, C Polo-Silva & A Delgado-Huertas. 2015. Population and individual foraging patterns of two hammerhead sharks using carbon and nitrogen stable isotopes. Rapid Communications in Mass Spectrometry 29(9):821-829.

Peñaherrera C, Y Llerena & I Keith. 2013. Perceptions of the economic value of sharks for single-day dive tourism and commerce in Santa Cruz Island. *In* Galapagos Report 2011-2012. Puerto Ayora, Galapagos, Ecuador.

Peñaherrera-Palma C. 2016. Abundance, distribution and conservation value of sharks in the Galapagos Marine Reserve. Doctor of Philosophy in Quantitative Marine Science. Institute for Marine and Antarctic Sciences, University of Tasmania. Hobart, Tasmania, Australia.

Penaherrera-Palma C, YY Llerena-Martillo, E Espinoza & J Semmens. 2015. Analysis of the perception of population trends for six shark species in the Galapagos Marine Reserve. *In* Galapagos Report 2013-2014.

Scuba-Diving. 2000. Reader´s Choice Awards Top Best 100 destinations, resorts and operators. Bonier Corporation. January / February Issue. 31.

Scuba-Diving. 2008. Top 100 Reader´s Choice Survey. Bonier Corporation.

Scuba-Diving. 2012. 2012 Top 100 Readers' Choice Awards. Bonier Corporation.

Soler GA, S Bessudo & A Guzmán. 2013. Long term monitoring of pelagic fishes at Malpelo Island, Colombia. Latin American Journal of Conservation 3(2):28-37.

White ER, MC Myers, JM Flemming & JK Baum. 2015. Shifting elasmobranch community assemblage at Cocos Island-an isolated marine protected area. Conservation Biology. 10.1111/cobi.12478