Scalloped hammerhead shark (Sphyrna lewini) 2014-2019

Trevor Riley, Head of Public Services, NOAA Central Library

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Bibliography

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Background & Scope

Scalloped hammerhead sharks are moderately large sharks with a global distribution. The most distinguishing characteristic of this shark is its "hammer-shaped" head. They are threatened by commercial fishing, mainly for the shark fin trade. Two distinct population segments of the scalloped hammerhead shark are listed as endangered and two are listed as threatened under the Endangered Species Act.

This bibliography focuses on any relevant scalloped hammerhead shark literature (peer-reviewed, technical reports, memos, biological opinions, International Whaling Commission (IWC) reports, etc) since 2014. It is intended as a reference resource for ESA staff of the NOAA Fisheries Office of Protected Resources when compiling and summarizing any relevant new (i.e. 2014-present) information for this shark species. It is organized into four sections: Biology and Life History, Genetics and Population Structure, Population Abundance and Trends, and Threats.

Section I – Biology and Life History

Section one is intended to provide an overview of new information since 2014 on the biology and life history of the scalloped hammerhead. The research in this area includes a compilation of diet, lifespan, habitat conditions, migration patterns, behavior, feeding, social ecology, and reproduction.

Section II – Genetics

Section two is intended to provide an overview of new information since 2014 on genetic diversity and trends, and population structure of the scalloped hammerhead shark.

Section III – Population Abundance and Trends

Section three is intended to provide an overview of the latest population estimates and trends (since 2014) for the scalloped hammerhead shark.

Section IV – Threats

A threat is defined as any factor that could represent an impediment to a species' recovery. Thus, section four is intended to provide an overview of any new and/or existing threats to the scalloped hammerhead shark. This may include targeted fisheries, bycatch in fisheries, inadequacy of existing state, national or international mechanisms/regulations, as well as current conservation efforts related to the scalloped hammerhead shark.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; Lexis Advance; ProQuest's Science and Technology including Aquatic Science Fisheries Abstracts; Elsevier's Science Direct; JSTOR; EBSCO's Academic Search Complete and Environment Complete; NOAA's Institutional Repository; the Biodiversity Heritage Library; BioOne Complete; and Google Scholar.

Section I: Biology and Life History

Alejo-Plata, M. D., Ahumada-Sempoal, M. A., de Guevara, G. C. L., & Gomez-Marquez, J. L. (2018). Population Structure and Reproductive Biology of the Hammerhead Sphyrna Lewini (Carcharhiniformes: Sphyrnidae) Caught in Artisanal Fisheries of Oaxaca, Mexico. *Hidrobiologica, 28*(3), 265-275 https://doi.org/10.24275/uam/izt/dcbs/hidro/2018v28n3/Alejo

Background: Sphyrna lewini is a semi-oceanic and cosmopolitan species globally distributed throughout tropical and warm temperate seas. In the northeastern tropical Pacific, this species is an important contributor to the biomass of artisanal fisheries. Goals: The aim of this study was to examine the length frequency distribution and reproductive aspects of S. lewini in Oaxaca, Mexico. Methods: Samples were taken from August 2001 to December 2007 in four landing sites of the artisanal fleet on the coast of Oaxaca. Results: The samples included 388 females and 434 males. Total length ranged from 44 to 332 cm for females and from 44 to 308 cm for males. The catches were made up of neonates (24.3%, 44-74 cm), juveniles (42.2%, 75-170 cm), and adults (33.5%, > 170 cm). The most abundant catches were recorded in the rainy season (85.5%), with a predominance of juveniles and adults, and a higher proportion of males. The remaining 15.5% of catches, recorded in the dry season, had a predominance of larger sizes (>100 cm) in both sexes. The females reached sexual maturity (TL50) at 199 cm and the males at 181 cm. 37 gravid females with sizes between 175 and 281 cm were registered from April to August. Gravid females had between 15-42 embryos, varying from 44-54 cm. Conclusion: The results of this study identify the coast of Oaxaca as an important area for the reproduction of S. lewini on the southern Pacific coast of Mexico, providing information for management and conservation of this species

Chin, A., Simpfendorfer, C. A., White, W. T., Johnson, G. J., McAuley, R. B., & Heupel, M. R. (2017). Crossing Lines: A Multidisciplinary Framework for Assessing Connectivity of Hammerhead Sharks across Jurisdictional Boundaries. *Scientific Reports, 7*, 14 https://doi.org/10.1038/srep46061

Conservation and management of migratory species can be complex and challenging. International agreements such as the Convention on Migratory Species (CMS) provide policy frameworks, but assessments and management can be hampered by lack of data and tractable mechanisms to integrate disparate datasets. An assessment of scalloped (Sphyrna lewini) and great (Sphyrna mokarran) hammerhead population structure and connectivity across northern Australia, Indonesia and Papua New Guinea (PNG) was conducted to inform management responses to CMS and Convention on International Trade in Endangered Species listings of these species. An Integrated Assessment Framework (IAF) was devised to systematically incorporate data across jurisdictions and create a regional synopsis, and amalgamated a suite of data from the Australasian region. Scalloped hammerhead populations are segregated by sex and size, with Australian populations dominated by juveniles and small adult males, while Indonesian and PNG populations included large adult females. The IAF process introduced genetic and tagging data to produce conceptual models of stock structure and movement. Several hypotheses were produced to explain stock structure and movement patterns, but more data are needed to identify the most likely hypothesis. This study demonstrates a process for assessing migratory species connectivity and highlights priority areas for hammerhead management and research.

Coiraton, C., Tovar-Avila, J., Garces-Garcia, K. C., Rodriguez-Madrigal, J. A., Gallegos-Camacho, R., Chavez-Arrenquin, D. A., & Amezcua, F. (2019). Periodicity of the Growth-Band Formation in Vertebrae of Juvenile Scalloped Hammerhead Shark Sphyrna Lewini from the Mexican Pacific Ocean. *Journal of Fish Biology*, 14 https://doi.org/10.1111/jfb.14100

The age of 296 juvenile scalloped hammerhead sharks Sphyrna lewini caught by several fisheries in the Mexican Pacific Ocean from March 2007 to September 2017 were estimated from growth band counts in thin-sectioned vertebrae. Marginal-increment analysis (MIA) and centrum-edge analysis (CEA) were used to verify the periodicity of formation of the growth bands, whereas elemental profiles obtained from LA-ICP-MS transect scans in vertebrae of 15 juveniles were used as an alternative approach to verify the age of the species for the first time. Age estimates ranged from 0 to 10+ years (42-158.7 cm total length; L-T). The index of average percentage error (I-APE 3.6%), CV (5.2%), bias plots and Bowker's tests of symmetry showed precise and low-biased age estimation. Both MIA and CEA indicated that in the vertebrae of juveniles of S. lewini a single translucent growth band was formed during winter (November-March) and an opaque band during summer (July-September), a period of faster growth, apparently correlated with a higher sea surface temperature. Peaks in vertebral P and Mn content spatially corresponded with the annual banding pattern in most of the samples, displaying 1.19 and 0.88 peaks per opaque band, respectively, which closely matched the annual deposition rate observed in this study. Although the periodicity of growth band formation needs to be verified for all sizes and ages representing the population of the species in the region, this demonstration of the annual formation of the growth bands in the vertebrae of juveniles should lead to a re-estimation of the growth parameters and productivity of the population to ensure that it is harvested at sustainable levels.

Drew, M., White, W. T., Dharmadi, Harry, A. V., & Huveneers, C. (2015). Age, Growth and Maturity of the Pelagic Thresher Alopias Pelagicus and the Scalloped Hammerhead Sphyrna Lewini. *Journal of Fish Biology, 86*(1), 333-354 https://doi.org/10.1111/jfb.12586

Indonesia has the greatest reported chondrichthyan catches worldwide, with c.110,000 t caught annually. The pelagic thresher (Alopias pelagicus) and scalloped hammerhead (Sphryna lewini) together comprise about 25% of the total catches of sharks landed in Indonesia. Age and growth parameters were estimated for A. pelagicus and S. lewini from growth-band counts of thin-cut vertebral sections. Alopias pelagicus (n = 158) and S. lewini (n = 157) vertebrae were collected from three Indonesian fish markets over a 5 year period. A multi-model analysis was used to estimate growth parameters for both species. The models of best fit for males and females for A. pelagicus was the three-parameter logistic ($L\infty$ = 3169 mm LT, k = 0·2) and the two-parameter von Bertalanffy models ($L\infty$ = 3281 mm LT, k = 0·12). Age at maturity was calculated to be 10·4 and 13·2 years for males and females, respectively, and these are the oldest estimated for this species. The samples of S. lewini were heavily biased towards females, and the model of best fit for males and females was the three-parameter Gompertz ($L\infty$ = 2598 mm LT, k = 0·15) and the two-parameter Gompertz ($L\infty$ = 2896 mm LT, k= 0·16). Age at maturity was calculated to be 8·9 and 13·2 years for males and females, respectively. Although numerous age and growth studies have previously been undertaken on S. lewini, few studies have been able to obtain adequate samples from all components of the population because adult females, adult males and juveniles often reside in different areas. For the first time, sex bias in this study was towards sexually mature females, which are commonly lacking in previous biological studies on S. lewini. Additionally, some of the oldest aged specimens and highest age at maturity for both species were observed in this study. Both species exhibit slow rates of growth and late age at maturity, highlighting the need for a re-assessment of the

relative resilience of these two globally threatened sharks at current high levels of fishing mortality throughout the eastern Indian Ocean.

Estupiñán-Montaño, C., Galván-Magaña, F., Tamburin, E., Sánchez-González, A., Villalobos-Ramírez, D., Murillo-Bohórquez, N., . . . Estupiñán-Montaño, J. (2017). Trophic Inference in Two Sympatric Sharks, Sphyrna Lewini and Carcharhinus Falciformis (Elasmobranchii: Carcharhiniformes), Based on Stable Isotope Analysis at Malpelo Island, Colombia. *Acta Ichthyologica Et Piscatoria, 47*(4), 357-364 https://doi.org/10.3750/aiep/02177

Elasmobranchs can play important roles in marine communities. But, relatively little is known about their diet, and movement. Sphyrna lewini (Griffith et Smith, 1834) consumes fishes, cephalopods, rays, and crustaceans. Carcharhinus falciformis (Müller et Henle, 1839) feed on fishes, cephalopods, crustaceans and sea turtles. To date, there are no studies available on the trophic ecology of sharks in Malpelo Island. The aim of this study was to describe the trophic ecology of S. lewini and C. falciformis, using stable isotope analysis of δ13δ15 N, to better understand the role of both shark species in the Malpelo Island ecosystem. In January, February, and November 2013, specimens of Sphyrna lewini and Carcharhinus falciformis illegally caught at Malpelo Island were confiscated at the port of Buenaventura, Colombia. For each shark specimen, total length and sex were registered. Samples of muscle tissue were taken from the nape of all specimens. Each muscle sample was lyophilized for 24 h and analysed with lipid and urea extraction and without extraction. For each shark specimen, a subsample of ~1.0 mg was used for isotopic analysis. A total of 14 Sphyrna lewini (Griffith et Smith, 1834) and 12 Carcharhinus falciformis (Müller et Henle, 1839) were analysed. δ13 C values were similar between S. lewini (–16.3 ± 0.1‰) and C. falciformis (–16.5 ± 0.1‰). N values of S. lewini (15.9 ± 0.11‰) were higher than those of C. falciformis (14.9 ± 0.09‰). In C. Sphyrna lewini showed a wider trophic niche than C. falciformis, with low trophic overlap (5%) between the two species. The δ15 falciformis, δ13 C values were similar in both sexes (–16.5 ± 0.1‰), while δ15 N values were significantly different between males (14.6 ± 0.1‰) and females (15.0 ± 0.1‰). The trophic position of S. lewini was 5.25 ± 0.12, and that of C. falciformis, 5.48 ± 0.18, which suggests that both shark species occupy a high position in the marine food chain.

Flores-Martínez, I. A., Torres-Rojas, Y. E., Galván-Magaña, F., & Ramos-Miranda, J. (2017). Diet Comparison between Silky Sharks (Carcharhinus Falciformis) and Scalloped Hammerhead Sharks (Sphyrna Lewini) Off the South-West Coast of Mexico. *Journal of the Marine Biological Association of the United Kingdom, 97*(2), 337-345 https://doi.org/10.1017/S0025315416000424

Ecologists examine diet composition in order to assess the spatial and temporal variations in interactions between species, the impact of different species traits on the ecological network structure, and the long-term effects of the removal of different species by small-scale fisheries. In this study, our goal was to compare the diets of silky sharks (Carcharhinus falciformis) and scalloped hammerhead sharks (Sphyrna lewini) off the south-west coast of Mexico in order to infer their diet preferences and spatial distributions. We sampled 164 S. lewini (96 stomachs had food, 68 were empty) and 183 C. falciformis (30 stomachs had food, 153 were empty) in Puerto Madero, Chiapas in 2011. The large number of empty stomachs may be the result of using longline fishing gear, which causes high stress resulting in regurgitation. Based on the index of relative importance (%IRI), the fish Chloroscombrus orqueta (IIR = 27.7%) was the most important species in the diet of S. lewini, while the squid Dosidicus gigas (IIR = 34%) was the primary prey of C. falciformis. Levin's index (Bi) and Shannon's index (H')

confirm that both sharks are generalists, as in other regions. The trophic levels of S. lewini (TL = 4.1) and C. falciformis (TL = 4.2) are characteristic of tertiary consumers; meanwhile, the Morisita–Horn index indicates low interspecific overlap between all categories. These results confirm that these two sharks have different foraging preferences or movement patterns; thus, there is no trophic overlap between species as they play unique roles in the ecological network off the south-west coast of Mexico.

Gallagher, A. J., Hammerschlag, N., Shiffman, D. S., & Giery, S. T. (2014). Evolved for Extinction: The Cost and Conservation Implications of Specialization in Hammerhead Sharks. *Bioscience, 64*(7), 619-624 https://doi.org/10.1093/biosci/biu071

The interactions between the evolutionary history of species and contemporary changes in their environment can result in both positive and negative outcomes for fitness and survival. Sharks are one the oldest groups of all extant vertebrates but, today, are among the most threatened globally, primarily because of destructive fishing practices. Hammerhead sharks (Sphyrnidae) exhibit extremely specialized traits and complex behaviors that have increased their vulnerability to human exploitation, which impedes conservation efforts. By bringing together published data on aspects of hammerhead shark phylogeny, morphology, biology, physiology, and ecology, we argue that the same novel adaptations that have historically contributed to evolutionary success have become maladaptive under current levels and modes of exploitation. Therefore, we suggest that future management be made in light of—rather than in spite of—the unique evolutionary and ecological traits possessed by hammerhead sharks, because similar patterns are threatening other taxa with high extinction risk.

Gallagher, A. J., & Klimley, A. P. (2018). The Biology and Conservation Status of the Large Hammerhead Shark Complex: The Great, Scalloped, and Smooth Hammerheads. *Reviews in Fish Biology and Fisheries, 28*(4), 777-794 https://doi.org/10.1007/s11160-018-9530-5

Hammerhead sharks are among the most intriguing yet imperiled groups of large sharks globally. Until recently, our understanding of their biology, movements, diet, and life histories was challenged by a lack of studies. In recent years there has been a surge of published studies on this group of sharks, incorporating new information on age and growth, behavior, and the threats they face. Here we summarize and compare what is known on the biology and conservation of the three largest species of hammerhead sharks: the great hammerhead (Sphyrna mokarran), the scalloped hammerhead (Sphyrna lewini), and the smooth hammerhead (Sphyrna zygaena). We chose these species since they are the most well-studied of the hammerheads, and also because they are commonly captured in target and non-target fisheries worldwide. Thus, we also discuss population trends and the vulnerabilities of each species, and make recommendations for future studies on these fascinating and complex elasmobranch fishes.

Hideya, T., Susumu, H., Tsukasa, A., Chiyo, T., Gordon, E. G., & Tatsuya, S. (2019). Effects of Fasting and Refeeding on Intestinal Cell Proliferation and Apoptosis in Hammerhead Shark (Sphyrna Lewini). *OpenAIRE* Retrieved from https://explore.openaire.eu/search/publication?articleId=doajarticles::70fe2d4d286b0933426b173f994837b9

Objective: To examine the effects of fasting and refeeding on intestinal cell proliferation and apoptosis in an opportunistic predator, hammerhead shark (Sphyrna lewini) of elasmobranch fishes which are among the earliest known extant groups of vertebrates to have the valvular intestine typical for the primitive species. Methods: Animals were euthanized after 5-10 d of fasting or feeding, or after 10-day fasting and 5-day refeeding. Intestinal apoptosis and cell proliferation were assessed by using oligonucleotide detection assay, terminal deoxynucleotidyl transferase dUTP nick end labeling staining, and immunohistochemistry of proliferating cells nuclear antigen. Results: Plasma levels of cholesterol and glucose were reduced by fasting. Intestinal apoptosis generally decreased during fasting. Numerous apoptotic cells were observed around the tips of the villi, primarily in the epithelium in the fed sharks, whereas fewer labeled nuclei were detected in the epithelium of fasted sharks. Refeeding returned intestinal apoptosis to the level in the fed sharks. Proliferating cells were observed in the epithelium around the troughs of the villi and greater in number in fed sharks, whereas fewer labeled nuclei were detected in fasted sharks. Conclusions: The cell turnover is modified in both intestinal epithelia of the shark and the murines by fasting/feeding, but in opposite directions. The difference may reflect the feeding ecology of the elasmobranchs, primitive intermittent feeders.

Hoffmann, S. L., Warren, S. M., & Porter, M. E. (2017). Regional Variation in Undulatory Kinematics of Two Hammerhead Species: The Bonnethead (Sphyrna Tiburo) and the Scalloped Hammerhead (Sphyrna Lewini). *Journal of Experimental Biology, 220*(18), 3336-3343 https://doi.org/10.1242/jeb.157941

Hammerhead sharks (Sphyrnidae) exhibit a large amount of morphological variation within the family, making them the focus of many studies. The size of the laterally expanded head, or cephalofoil, is inversely correlated with pectoral fin area. The inverse relationship between cephalofoil and pectoral fin size in this family suggests that they might serve a complementary role in lift generation. The cephalofoil is also hypothesized to increase olfaction, electroreception and vision; however, little is known about how morphological variation impacts post-cranial swimming kinematics. Previous studies demonstrate that the bonnethead and scalloped hammerhead have significantly different yaw amplitude, and we hypothesized that these species utilize varied frequency and amplitude of undulation along the body. We analyzed video of free-swimming sharks to examine kinematics and 2D morphological variables of the bonnethead and scalloped hammerhead. We also examined the second moment of area along the length of the body and over a size range of animals to determine whether there were shape differences along the body of these species and whether those changed over ontogeny. We found that both species swim with the same standardized velocity and Strouhal number, but there was no correlation between two-dimensional morphology and swimming kinematics. However, the bonnethead has a dorso-ventrally compressed anterior trunk and undulates with greater amplitude, whereas the scalloped hammerhead has a laterally compressed anterior trunk and undulates with lower amplitude. We propose that differences in cross-sectional trunk morphology account for interspecific differences in undulatory amplitude. We also found that for both species, undulatory frequency is significantly greater in the anterior body compared with all other body regions. We hypothesize that the bonnethead and scalloped hammerhead swim with a double oscillation system

Hoyos-Padilla, E. M., Ketchum, J. T., Klimley, A. P., & Galván-Magaña, F. (2014). Ontogenetic Migration of a Female Scalloped Hammerhead Shark Sphyrna Lewini in the Gulf of California. *Animal Biotelemetry, 2*(1), 17 https://doi.org/10.1186/2050-3385-2-17

Little information exists on the vertical and horizontal movements of juvenile scalloped hammerhead sharks (Sphyrna lewini). Measurements of the sizes of juveniles caught in nets close to shore and those swimming in schools at seamounts and islands in the southwestern Gulf of California, Mexico indicate that at least part of the population undergoes a migration during their life cycle at a length of approximately 115 cm total length (TL) from coastal to offshore waters. Three juvenile hammerhead sharks were outfitted with archival tags in Mazatlan and La Paz Bay (LPB), Mexico during February 2006 and January 2007, respectively.

Juste-Poinapen, N. M. S., Yang, L., Ferreira, M., Poinapen, J., & Rico, C. (2019). Community Profiling of the Intestinal Microbial Community of Juvenile Hammerhead Sharks (Sphyrna Lewini) from the Rewa Delta, Fiji. *Scientific Reports, 9*(1), 7182 https://doi.org/10.1038/s41598-019-43522-x

Fourteen juvenile scalloped hammerhead sharks (Sphyrna lewini; SHS) were captured between November and December 2014 in the Rewa Delta in Fiji, and assessed for intestinal microflora characterisation using 16S rRNA amplicon sequencing by Illumina Miseq. The microbial population revealed a fluctuating dominance between the Enterobacteriaceae and Vibrionaceae families, namely Citrobacter and Photobacterium spp. Other related marine operational taxonomic units were closely related to Afipia felis, Chloroflexus aggregans, Psychrobacter oceani, Pontibacter actiniarum and Shigella sonnei. Two sharks had distinctive profiles that were dominated by known pathogens, namely Aeromonas salmonicida and Klebsiella pneumonia. The presence of a Methanosaeta species, and of Shigella and Psychrobacter, would suggest sewage contamination because of a spill that occurred on the 6th of December 2014. This study successfully establishes a baseline for future research.

Ketchum, J. T., Hearn, A., Klimley, A. P., Espinoza, E., Peñaherrera, C., & Largier, J. L. (2014). 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 https://doi.org/10.1007/s00227-013-2375-5

Movements and habitat preferences of sharks relative to a central location are widely documented for many species; however, the reasons for such behaviors are currently unknown. Do movements vary spatially or temporally or between individuals? Do sharks have seasonal habitat and environmental preferences or simply perform movements at random at any time of the year? To help understand requirements for the designation of critical habitats for an endangered top predator and to develop zoning and management plans for key habitats, we examined vertical and horizontal movements, and determined habitat and environmental preferences of scalloped hammerhead sharks (Sphyrna lewini). We tracked seven hammerheads for 19–96 h at Wolf Island (1.38ºN, 91.82ºW) between 2007 and 2009 using ultrasonic transmitters with depth and temperature sensors, and we profiled temperature through the water column. Movements of individual hammerheads fell in two classes: constrained (remaining near the island) and dispersive (moving offshore to pelagic environments). The central activity space or kernel off the southeast side of Wolf Island was small and common to most, but the area varied among individuals (mean ± SE 0.25 ± 0.2 km2), not exceeding 0.6 km2 for any of the sharks, and not changing significantly between seasons. In general, hammerheads showed preference for the up-current habitat

on the eastern side of Wolf Island in both the warm and cold seasons. However, the depth of sharks varied with season, apparently in response to seasonal changes in the vertical structure of temperature. Hammerheads performed frequent vertical excursions above the thermocline during offshore movements and, in general, were observed to prefer temperatures of 23–26 °C found above the thermocline. At times, though individuals moved into the thermocline and made brief dives below it. Our results provided evidence that hammerheads (1) are highly selective of location (i.e., habitat on up-current side of island) and depth (i.e., top of the thermocline) while refuging, where they may carry out essential activities such as cleaning and thermoregulation, and (2) perform exploratory vertical movements by diving the width of the mixed layer and occasionally diving below the thermocline while moving offshore, most likely for foraging.

Ketchum, J. T., Hearn, A., Klimley, A. P., Peñaherrera, C., Espinoza, E., Bessudo, S., . . . Arauz, R. (2014). Inter-Island Movements of Scalloped Hammerhead Sharks (Sphyrna Lewini) and Seasonal Connectivity in a Marine Protected Area of the Eastern Tropical Pacific. *Marine Biology, 161*(4), 939-951 https://doi.org/10.1007/s00227-014-2393-y

Marine top predators are common at offshore bathymetric features such as islands, atolls, and seamounts, where most pelagic reef fish reside, while certain sharks perform inter-island movements between these formations. Scalloped hammerhead sharks are known to school in great numbers at small islands and seamounts in the eastern tropical Pacific (ETP) and are very susceptible to fisheries while moving into the open sea. It is, therefore, essential to understand hammerhead inter-island movements and environmental effects to provide baseline information for their conservation and management within and beyond an insular marine protected area. Movements of scalloped hammerheads were analyzed in the Galapagos Marine Reserve (GMR) and ETP, and environmental factors were linked to their movements. Hammerheads were tagged (N = 134) with V16 coded pingers (July 2006 to July 2010) in the northern Galapagos and detected at listening stations around four islands in the GMR and two isolated islands in the ETP, 700 and 1,200 km away. Hammerheads formed daytime schools at specific locations, but dispersed at night. Overall, more daytime than nighttime detections were recorded at all receivers in the northern Galapagos Islands, and more detections in the up-current sides of these islands. Hammerheads remained more days at the northern islands during part of the warm season (December–February) compared to the cool; however, fewer individuals were present in March–June. Movement modes were diel island excursions (24-h cycles) in the northern Galapagos and inter-island in the GMR and ETP at different scales: (1) short back-and-forth (<50 km, SBF), <5 days cycles, (2) medium distance (50–300 km, MDT), 5–20 days, and (3) long distance (>300 km, LDT), 15–52 days. The high degree of inter-island connectivity of hammerheads within the northern GMR is striking compared to the almost nil movement to the central GMR. A seasonal migratory pattern to locations offshore is indicated by (1) fewer hammerheads observed in the northern GMR during part of the warm season (March–June) and (2) evidence of LDT movements from the northern GMR to other islands in the ETP. LDT movements of mature female hammerheads are possibly associated with pupping areas. Our results indicate that currents, season, and individual behavior mainly drive inter-island movements of hammerheads at small (SBF) and medium (MDT) scales. These findings have important implications for the management of a highly mobile and endangered top predator within a marine protected area and beyond.

Marie, A. D., Miller, C., Cawich, C., Piovano, S., & Rico, C. (2017). Fisheries-Independent Surveys Identify Critical Habitats for Young Scalloped Hammerhead Sharks (Sphyrna Lewini) in the Rewa Delta, Fiji. *Scientific Reports, 7*, 12 https://doi.org/10.1038/s41598-017-17152-0

Sharp declines in numerous shark populations around the world have generated considerable interest in better understanding and characterising their biology, ecology and critical habitats. The scalloped hammerhead shark (SHS, Sphyrna lewini) is subject to a multitude of natural and anthropogenic threats that are often exacerbated within the coastal embayments and estuaries used during SHS early life stages. In this study, we describe the temporal and spatial distribution, age class composition, and reproductive biology of SHS in the Rewa Delta (RD), Fiji. A total of 1054 SHS (including 796 tagged individuals; 101 of which were recaptured) were captured from September 2014 to March 2016 in the RD. A majority of the captures in this area were neonates and young-of-the-year (YOY) (99.8%). Significant seasonality in patterns of occurrence of both neonates and YOY individuals suggests a defined parturition period during the austral summer. Between the seven sampling sites in the RD we also found significant differences in SHS neonate catch per unit of effort, and average total length of individuals. According to the data, the RD is likely to represent an important nursery area for SHS up to one year of age.

Moore, A. B. M., & Gates, A. R. (2015). Deep-Water Observation of Scalloped Hammerhead Sphyrna Lewini in the Western Indian Ocean Off Tanzania. *Marine Biodiversity Records, 8*, https://doi.org/10.1017/S1755267215000627

A scalloped hammerhead Sphyrna lewini was observed opportunistically from a remotely operated vehicle 1 m off the seabed at 1042 m depth, during hydrocarbon exploration activities in the Ruvuma Basin off Tanzania. The observation, which occurred during night hours, is the deepest accurately recorded for this species and the first deep-water record for the Indian Ocean. The record adds support for the occurrence in deep water during night hours being a widespread and possibly common behaviour in this species, and further expands a small but growing literature that meso- and bathypelagic environments may be of greater importance to elasmobranchs previously considered to be primarily epipelagic.

Nalesso, E., Hearn, A., Sosa-Nishizaki, O., Steiner, T., Antoniou, A., Reid, A., . . . Arauz, R. (2019). Movements of Scalloped Hammerhead Sharks (Sphyrna Lewini) at Cocos Island, Costa Rica and between Oceanic Islands in the Eastern Tropical Pacific. *PLoS One, 14*(3), 16 https://doi.org/10.1371/journal.pone.0213741

Many species of sharks form aggregations around oceanic islands, yet their levels of residency and their site specificity around these islands may vary. In some cases, the waters around oceanic islands have been designated as marine protected areas, yet the conservation value for threatened shark species will depend greatly on how much time they spend within these protected waters. Eighty-four scalloped hammerhead sharks (Sphyrna lewini Griffith & Smith), were tagged with acoustic transmitters at Cocos Island between 2005-2013. The average residence index, expressed as a proportion of days present in our receiver array at the island over the entire monitoring period, was 0.52 +/- 0.31, implying that overall the sharks are strongly associated with the island. Residency was significantly greater at Alcyone, a shallow seamount located 3.6 km offshore from the main island, than at the other sites. Timing of presence at the receiver locations was mostly during daytime hours. Although only a single individual

from Cocos was detected on a region-wide array, nine hammerheads tagged at Galapagos and Malpelo travelled to Cocos. The hammerheads tagged at Cocos were more resident than those visiting from elsewhere, suggesting that the Galapagos and Malpelo populations may use Cocos as a navigational waypoint or stopover during seasonal migrations to the coastal Central and South America. Our study demonstrates the importance of oceanic islands for this species, and shows that they may form a network of hotspots in the Eastern Tropical Pacific.

Roemer, R. P., Gallagher, A. J., & Hammerschlag, N. (2016). Shallow Water Tidal Flat Use and Associated Specialized Foraging Behavior of the Great Hammerhead Shark (Sphyrna Mokarran). *Marine and Freshwater Behaviour and Physiology, 49*(4), 235-249 https://doi.org/10.1080/10236244.2016.1168089

Evidence suggests the great hammerhead shark, Sphyrna mokarran, is vulnerable to a variety of anthropogenic stressors, and is an understudied species of shark due to its cryptic nature and wide-ranging movements. While recognized as both a pelagic-coastal and a highly mobile predator, minimal anecdotal evidence exist describing shallow water habitat use by this species. This report describes six cases in which a great hammerhead shark utilizes an inshore shallow water flats environment (<1.5 m in depth), five of which involve prey capture. These observations permitted identification of two novel behaviors that may allow great hammerheads to inhabit these shallow habitats: a (1) prey-capture technique termed 'grasp-turning' that involves burst swimming at tight turning angles while grasping prey and (2) a post-predation recovery period whereby the shark maintains head-first orientation into the current that may facilitate respiration and prey consumption. These behavioral observations provide insights into the natural history of this species.

Rojas, Y. E. T., Osuna, F. P., Herrera, A. H., Magaña, F. G., García, S. A., Villalobos Ortíz, H., & Sampson, L. (2014). Feeding Grounds of Juvenile Scalloped Hammerhead Sharks (Sphyrna Lewini) in the South-Eastern Gulf of California. *Hydrobiologia, 726*(1), 81-94 https://doi.org/10.1007/s10750-013-1753-9

The aim of this study was to determine whether juvenile scalloped hammerhead sharks (Sphyrna lewini) use the south-eastern Gulf of California as a nursery and feeding area. This information could help lay the groundwork required for the conservation of this endangered species. To address this, we carried out stable isotope (δ15N and δ13C) and stomach content analyses of sharks caught between 2000 and 2004 in Mazatlan, Mexico. Stomach contents and δ13C values indicated that S. lewini is a predator that feeds on benthic prey near the coast. Differences in δ15N average values between sizes classes (<100 vs. >100 cm) suggest that there was an ontogenetic change in this shark's feeding habits and also in their living environment (from benthic areas to pelagic areas). The trophic position indicated that S. lewini is a tertiary consumer, but with a high degree of trophic plasticity, and thus, different trophic roles, highlighting the importance of this predator as a regulator of prey populations. Finally, the linear isotopic relationship between S. lewini and its prey indicates a long residency within the Mazatlan area. Our results demonstrate that the south-eastern Gulf of California is a nursery area that offers abundant food for juvenile scalloped hammerhead sharks.

Rooker, J. R., Dance, M. A., Wells, R. J. D., Ajemian, M. J., Block, B. A., Castleton, M. R., . . . Walter, J. F. (2019). Population Connectivity of Pelagic Megafauna in the Cuba-Mexico-United States Triangle. *Scientific Reports, 9*(1), 1663 https://doi.org/10.1038/s41598-018-38144-8

The timing and extent of international crossings by billfishes, tunas, and sharks in the Cuba-Mexico-United States (U.S.) triangle was investigated using electronic tagging data from eight species that resulted in >22,000 tracking days. Transnational movements of these highly mobile marine predators were pronounced with varying levels of bi- or tri-national population connectivity displayed by each species. Billfishes and tunas moved throughout the Gulf of Mexico and all species investigated (blue marlin, white marlin, Atlantic bluefin tuna, yellowfin tuna) frequently crossed international boundaries and entered the territorial waters of Cuba and/or Mexico. Certain sharks (tiger shark, scalloped hammerhead) displayed prolonged periods of residency in U.S. waters with more limited displacements, while whale sharks and to a lesser degree shortfin mako moved through multiple jurisdictions. The spatial extent of associated movements was generally associated with their differential use of coastal and open ocean pelagic ecosystems. Species with the majority of daily positions in oceanic waters off the continental shelf showed the greatest tendency for transnational movements and typically traveled farther from initial tagging locations. Several species converged on a common seasonal movement pattern between territorial waters of the U.S. (summer) and Mexico (winter).

Rosa, D., Coelho, R., Fernandez-Carvalho, J., & Santos, M. N. (2017). Age and Growth of the Smooth Hammerhead, Sphyrna Zygaena, in the Atlantic Ocean: Comparison with Other Hammerhead Species. *Marine Biology Research, 13*(3), 300-313 https://doi.org/10.1080/17451000.2016.1267366

The smooth hammerhead Sphyrna zygaena (Sphyrnidae) is a pelagic shark occasionally caught as bycatch in pelagic longline fisheries, but is one of the least studied of all pelagic sharks. Age and growth of S. zygaena was studied along a wide Atlantic region covering both the northern and southern hemispheres. Data from 304 specimens, caught between October 2009 and September 2014, ranging in size from 126 to 253 cm fork length (FL), were analysed. Growth models were fitted using the three-parameter von Bertalanffy growth function (VBGF) re-parameterized to calculate L-0 (size at birth). Growth models were fitted to the sample data and data from several back-calculation models. The model fit to the quadratic modified Dahl-Lea back-calculated data seems to be the most appropriate to describe growth in this species, with resulting growth parameters of L-inf = 285 cm FL, k = 0.09 year(-1) for males and Linf = 293 cm FL, k = 0.09 year(-1) for females. Compared with other species of the same genus, estimated growth coefficients for S. zygaena seem to fall in the low to middle range. Although further work is still needed, this study adds to knowledge of the vital life-history parameters of smooth hammerheads in the Atlantic Ocean, which can be used in the management and conservation of this species.

Rosende-Pereiro, A., & Corgos, A. (2018). Pilot Acoustic Tracking Study on Young of the Year Scalloped Hammerhead Sharks, Sphyrna Lewini, within a Coastal Nursery Area in Jalisco, Mexico. *Latin American Journal of Aquatic Research, 46*(4), 645-659 https://doi.org/10.3856/vol46-issue4-fulltext-2

A preliminary experience to study, on a small scale, the movements of the young of the year (YOY) Sphyrna lewini (Griffith & Smith, 1834), in the Mexican Central Pacific, using acoustic telemetry within a

nursery area. From October to December 2014 seven sharks were tagged with ultrasonic transmitters and tracked for 68 days within a 14 km2 area associated to a river mouth. The quick shark handling allowed their release in less than two minutes and excellent health condition. Although recaptured sharks up to 105 days after tagging did not show symptoms of scar infection, a slight abrasion in the shark skin was observed after 51 days. The ultrasonic transmitter retention was 75%, and the site fidelity was complete (F = 1) during the first ninety days. For the 135-day period, fidelity was 0.63 (0.40-0.80), and the estimated attrition rate was 0.73 (0.34-1). Ninety-seven percent of detections occurred on soft bottoms and less than 30 m depth. The YOY S. lewini stayed active 24 h a day and performed estimated movements of 11.96 km during that time. The home range for all tagged sharks was estimated to be 4.82 km2 using the minimum convex polygon method (MCP) and 4.89 km2 using the kernel utilization distribution method (95% KUD). The KUD estimation showed two core areas within the study area, is the one located in front of the river mouth the most used.

Salinas-de-Leon, P., Hoyos-Padilla, E. M., & Pochet, F. (2017). First Observation on the Mating Behaviour of the Endangered Scalloped Hammerhead Shark Sphyrna Lewini in the Tropical Eastern Pacific. *Environmental Biology of Fishes, 100*(12), 1603-1608 https://doi.org/10.1007/s10641-017-0668-0

Here we provide a detailed analysis of the first complete sequence of a mating event for the endangered scalloped hammerhead shark, Sphyrna lewini. This analysis is based on a mating event recorded at Isla del Coco National Park, Costa Rica, where large schools of hammerhead sharks are frequently encountered. S lewini mating sequence can be characterized by: (1) an open water encounter, (2) pre-copulatory biting, (3) grabbing of pectoral fin/copulation, (4) free fall, (5) separation and (6) following. Based on this single observation we found that only one male appears to be involved in a copulation cycle and that mating took place in a high current zone potentially to favor respiration when both individuals are unable to swim. This observation highlights the difficulty in observing mating behavior for this species since mating is likely to occur in open waters.

Spaet, J. L. Y., Lam, C. H., Braun, C. D., & Berumen, M. L. (2017). Extensive Use of Mesopelagic Waters by a Scalloped Hammerhead Shark (Sphyrna Lewini) in the Red Sea. *Animal Biotelemetry, 5*(1), 20 https://doi.org/10.1186/s40317-017-0135-x

Despite being frequently landed in fish markets along the Saudi Arabian Red Sea coast, information regarding fundamental biology of the Scalloped hammerhead shark (Sphyrna lewini) in this region is scarce. Satellite telemetry studies can generate important data on life history, describe critical habitats, and ultimately redefine management strategies for sharks. To better understand the horizontal and vertical habitat use of S. lewini in the Red Sea and to aid with potential future development of zoning and management plans for key habitats, we deployed a pop-up satellite archival transmitting tag to track a single female specimen (240 cm total length) for a tracking period of 182 days.

Spaet, J. L. Y., Lam, C. H., & Braun, C. D. (2017). *Scalloped Hammerhead Shark (Sphyrna Lewini) Tracking Records in the Red Sea, Supplement To: Spaet, Julia L Y; Lam, Chin Hin; Braun, Camrin D; Berumen, Michael L (2017): Extensive Use of Mesopelagic Waters by a Scalloped Hammerhead Shark (Sphyrna Lewini) in the Red Sea. Animal Biotelemetry, 5(1), 1-12*. https://doi.pangaea.de/10.1594/PANGAEA.880113

Despite being frequently landed in fish markets along the Saudi Arabian Red Sea coast, information regarding fundamental biology of the Scalloped hammerhead shark (Sphyrna lewini) in this region is scarce. Satellite telemetry studies can generate important data on life history, describe critical habitats, and ultimately redefine management strategies for sharks. To better understand the horizontal and vertical habitat use of S. lewini in the Red Sea and to aid with potential future development of zoning and management plans for key habitats, we deployed a pop-up satellite archival transmitting tag to track a single female specimen (240 cm total length) for a tracking period of 182 days. The tag was physically recovered after a deployment period of 6 months, thus providing the complete archived dataset of more than one million depth and temperature records. Based on a reconstructed, most probable track, the shark travelled a circular distance of approximately 1000 km from the central Saudi Arabian Red Sea south- eastward into Sudanese waters, returning to the tagging location toward the end of the tracking period. Mesopelagic excursions to depths between 650 and 971 m occurred on 174 of the 182 days of the tracking period. Intervals between such excursions were characterized by constant oscillatory diving in the upper 100 m of the water column. This study provides evidence that mesopelagic habitats might be more commonly used by S. lewini than previously suggested. We identified deep diving behavior throughout the 24-h cycle over the entire 6-month tracking period. In addition to expected nightly vertical habitat use, the shark exhibited frequent mesopelagic excursions during daytime. Deep diving throughout the diel cycle has not been reported before and, while dive functional- ity remains unconfirmed, our study suggests that mesopelagic excursions may represent foraging events within and below deep scattering layers. Additional research aimed at resolving potential ecological, physiological and behavioral mechanisms underpinning vertical movement patterns of S. lewini will help to determine if the single individual reported here is representative of S. lewini populations in the Red Sea.

Tickler, D. M., Letessier, T. B., Koldewey, H. J., & Meeuwig, J. J. (2017). Drivers of Abundance and Spatial Distribution of Reef-Associated Sharks in an Isolated Atoll Reef System. *PLoS One, 12*(5), https://doi.org/10.1371/journal.pone.0177374

We investigated drivers of reef shark demography across a large and isolated marine protected area, the British Indian Ocean Territory Marine Reserve, using stereo baited remote underwater video systems. We modelled shark abundance against biotic and abiotic variables at 35 sites across the reserve and found that the biomass of low trophic order fish (specifically planktivores) had the greatest effect on shark abundance, although models also included habitat variables (depth, coral cover and site type). There was significant variation in the composition of the shark assemblage at different atolls within the reserve. In particular, the deepest habitat sampled (a seamount at 70-80m visited for the first time in this study) recorded large numbers of scalloped hammerhead sharks (Sphyrna lewini) not observed elsewhere. Size structure of the most abundant and common species, grey reef sharks (Carcharhinus amblyrhynchos), varied with location. Individuals at an isolated bank were 30% smaller than those at the main atolls, with size structure significantly biased towards the size range for young of year (YOY). The 18 individuals judged to be YOY represented the offspring of between four and six females, so, whilst inconclusive, these data suggest the possible use of a common pupping site by grey reef sharks. The importance of low trophic order fish biomass (i.e. potential prey) in predicting spatial variation in shark abundance is consistent with other studies both in marine and terrestrial systems which suggest that prey availability may be a more important predictor of predator distribution than habitat suitability. This result supports the need for ecosystem level rather than species-specific conservation measures to support shark recovery. The observed spatial partitioning amongst sites for species and life-stages also

implies the need to include a diversity of habitats and reef types within a protected area for adequate protection of reef-associated shark assemblages.

Tristram, H., Thomas, S., & Squire, L. (2014). Husbandry of Scalloped Hammerhead Sharks Sphyrna Lewini (Griffith & Smith, 1834) at Reef Hq Aquarium, Townsville, Australia. *Der Zoologische Garten, 83*(4), 93-113 https://doi.org/10.1016/j.zoolgart.2014.08.002

Reef HQ Aquarium (Townsville, Australia) has successfully hosted two scalloped hammerhead sharks (Sphyrna lewini) in captivity in its 2.5 ML Coral Reef Exhibit since late 2011. Here we document this experience after 2.5 years including collection and period of acclimation to captivity, transport, introduction into display, husbandry issues encountered, behavioural observations, health and growth observations, and management considerations.

Xue-Rong, L., Chang-Feng, C., Li, L., & Bin, W. (2017). Purification and Identification of Antioxidant Peptides from Protein Hydrolysate of Scalloped Hammerhead (Sphyrna Lewini) Cartilage. *Marine Drugs, 15*(3), 61 https://doi.org/10.3390/md15030061

The aim of this study was to purify and identify peptides with antioxidant properties from protein hydrolysate of scalloped hammerhead (Sphyrna lewini) cartilage. Cartilaginous proteins of the scalloped hammerhead were extracted by guanidine hydrochloride, and three antioxidant peptides, named enzymolysis peptide of scalloped hammerhead cartilage A (SCPE-A), SCPE-B and SCPE-C, were subsequently isolated from the hydrolysate of the cartilaginous proteins using ultrafiltration and chromatography. The amino acid sequences of SCPE-A, SCPE-B and SCPE-C were identified as Gly-Pro-Glu (GPE), Gly-Ala-Arg-Gly-Pro-Gln (GARGPQ), and Gly-Phe-Thr-Gly-Pro-Pro-Gly-Phe-Asn-Gly (GFTGPPGFNG), with molecular weights of 301.30 Da, 584.64 Da and 950.03 Da, respectively. As per in vitro activity testing, SCPE-A, SCPE-B and SCPE-C exhibited strong scavenging activities on 2,2-diphenyl-1-picrylhydrazyl radicals (DPPH*) (half elimination ratio (EC50) 2.43, 2.66 and 1.99 mg/mL), hydroxyl radicals (HO*) (EC50 0.28, 0.21 and 0.15 mg/mL), 2,20 -azino-bis-3-ethylbenzothiazoline-6-sulfonic acid radicals (ABTS+*) (EC50 0.24, 0.18 and 0.29mg/mL), and superoxide anion radicals (O2-*) (EC50 0.10, 0.14 and 0.11mg/mL). In addition, SCPE-A showed inhibition activity similar to butylated hydroxytoluene (BHT) in lipid peroxidation in a linoleic acid model system. The amino acid residues of Gly, Pro and Phe could positively influence the antioxidant activities of GPE, GARGPQ and GFTGPPGFNG. These results suggested that GPE, GARGPQ and GFTGPPGFNG might serve as potential antioxidants and be used as food additives and functional foods.

Section II: Genetics

Barker, A. M., Adams, D. H., Driggers, W. B., Frazier, B. S., & Portnoy, D. S. (2019). Hybridization between Sympatric Hammerhead Sharks in the Western North Atlantic Ocean. *Biology Letters, 15*(4), 5 https://doi.org/10.1098/rsbl.2019.0004

Hybridization between closely related species has been documented across a wide range of taxa but has not been well studied in elasmobranchs. Hammerhead sharks have drawn global conservation concern because they experience some of the highest mortality rates among sharks when interacting with fisheries. Here we report on the detection of hybrids between the globally distributed scalloped hammerhead (Sphyrna lewini) and recently described Carolina hammerhead (S. gilberti) which are only known from the western Atlantic Ocean. Using a genomics approach, 10 first-generation hybrids and 15-17 backcrosses were detected from 554 individuals. The identification of backcrosses demonstrates hybrids are viable, and all backcrosses but one involved a scalloped hammerhead. All hybrids but one possessed Carolina hammerhead mtDNA, indicating sex-biased gene flow between species. Repeated hybridization and backcrossing with scalloped hammerheads could lead to the loss of endemic Carolina hammerheads.

Chen, X., Xiang, D., Xu, Y., & Shi, X. (2015). Complete Mitochondrial Genome of the Scalloped Hammerhead Sphyrna Lewini (Carcharhiniformes: Sphyrnidae). *Mitochondrial DNA, 26*(4), 621-622 https://doi.org/10.3109/19401736.2013.834432

AbstractThe complete mitochondrial genome of the endangered scalloped hammerhead Sphyrna lewini was firstly determined in this study. It is 16,726?bp in length with the typical gene composition and orders in vertebrates. The overall base composition is 31.4% A, 26.3% C, 13.2% G and 29.1% T. Two start codon (ATG and GTG) and three stop codon (TAG, AGA and TAA/TA/T) patterns were found in protein-coding genes. Except for the tRNA-Ser2, the remaining 21 tRNAs can be folded into the typical cloverleaf structure. The control region possess the highest A+T content (66.1%) and lowest G content (12.6%) among all mitochondrial partitions.

Feitosa, L. M., Martins, A. P. B., Giarrizzo, T., Macedo, W., Monteiro, I. L., Gemaque, R., . . . Carvalho-Costa, L. F. (2018). DNA-Based Identification Reveals Illegal Trade of Threatened Shark Species in a Global Elasmobranch Conservation Hotspot. *Scientific Reports, 8*(1), 3347 https://doi.org/10.1038/s41598-018-21683-5

Here, we report trading of endangered shark species in a world hotspot for elasmobranch conservation in Brazil. Data on shark fisheries are scarce in Brazil, although the northern and northeastern regions have the highest indices of shark bycatch. Harvest is made primarily with processed carcasses lacking head and fins, which hampers reliable species identification and law enforcement on illegal catches. We used partial sequences of two mitochondrial genes (COI and/or NADH2) to identify 17 shark species from 427 samples being harvested and marketed on the northern coast of Brazil. Nine species (53%) are listed under some extinction threat category according to Brazilian law and international authorities (IUCN – International Union for Conservation of Nature; CITES – Convention on International Trade of Endangered Species of Wild Fauna and Flora). The number increases to 13 (76%) if we also consider the Near Threatened category. Hammerhead sharks are under threat worldwide, and composed 18.7% of samples, with Sphyrna mokarran being the fourth most common species among samples. As illegal trade

of threatened shark species is a worldwide conservation problem, molecular identification of processed meat or specimens lacking diagnostic body parts is a highly effective tool for species identification and law enforcement.

Hadi, S., Anggraini, N. P., Muttaqin, E., Simeon, B. M., Subhan, B., & Madduppa, H. (2019). Genetic Diversity of the Endangered Species Sphyrna Lewini (Griffith and Smith 1834) in Lombok Based on Mitochondrial DNA. In *1st International Conference on Fisheries and Marine Science.* A. T. Mukti, L. Sulmartiwi, & A. S. Mubarak (Eds.), (Vol. 236). Bristol: Iop Publishing Ltd https://doi.org/10.1088/1755-1315/236/1/012024

Sphyrna lewini is a shark with a wide distribution and one of the most endangered species. Although The International Union for Conservation of Nature (IUCN) classified this species as endangered and the species was already protected by law in Indonesia, S. lewini are currently high exploited because of their high economic value. This study conducted to analyze the genetic diversity and phylogenetic reconstruction the S. lewini landed in Lombok (n = 30) using a molecular approach based on the mitochondrial DNA. DNA amplification with the CO1 gene successfully identified 30 individuals of S. lewini with an average 625-bp nucleotide length. The value of haplotype diversity in Lombok (Hd) = 0.40 and nu pi = 0.0018. The results of phylogenetic analysis using Neighbor-Joining (NJ) by Kimura 2-parameter model with 1000 bootstrap showed the connectivity of S. lewini landed in Lombok in 1 Glade of 5 haplotypes. This study showed that low genetic diversity and significant differences in genetic structure between populations made this species vulnerable to extinction in Indonesia and required special treatment.

Quintanilla, S., Gomez, A., Marino-Ramirez, C., Sorzano, C., Bessudo, S., Soler, G., . . . Caballero, S. (2015). Conservation Genetics of the Scalloped Hammerhead Shark in the Pacific Coast of Colombia. *Journal of Heredity, 106*, 448-458 https://doi.org/10.1093/jhered/esv050

Previous investigations of the population genetics of the scalloped hammerhead sharks (Sphyrna lewini) in the Eastern Tropical Pacific have lacked information about nursery areas. Such areas are key to promoting conservation initiatives that can protect young sharks from threats such as overfishing. Here, we investigated the genetic diversity, phylogeography, and connectivity of S. lewini found in 3 areas of Colombia's Pacific coast: around Malpelo Island and in 2 National Natural Parks on the Colombian Pacific mainland (Sanquianga and Ensenada de Utria). We analyzed mtDNA control region (CR) sequences and genotyped 15 microsatellite loci in 137 samples of adults and juveniles. The mtDNA analyses showed haplotypes shared between the Colombian Pacific individuals sampled in this investigation and other areas in the Eastern Tropical Pacific, the Indo-Pacific, and with sequences previously reported in Colombia (Buenaventura Port), as well as 4 unique haplotypes. Population assignment and paternity analyses detected 3 parent-offspring pairs between Malpelo and Sanquianga and 1 between Malpelo and Utria. These results indicate high genetic connectivity between Malpelo Island and the Colombian Pacific coast, suggesting that these 2 areas are nurseries for S. lewini. This is, to our knowledge, the first evidence of nursery areas identified for the scalloped hammerhead shark anywhere in the world. Additional conservation planning may be required to protect these nursery habitats of this endangered shark species.

Rossouw, C., Wintner, S. P., & Bester-Van Der Merwe, A. E. (2016). Assessing Multiple Paternity in Three Commercially Exploited Shark Species: Mustelus Mustelus, Carcharhinus Obscurus and Sphyrna Lewini. *Journal of Fish Biology, 89*(2), 1125-1141 https://doi.org/10.1111/jfb.12996

In this study, multiple paternity (MP) was investigated in three commercially important shark species, common smoothhound Mustelus mustelus, dusky shark Carcharhinus obscurus and scalloped hammerhead Sphyrna lewini occurring in southern Africa. Reduced marker panels of between five and six microsatellite loci were constructed for each species and used to genotype and assess the presence of MP in a total of 60 M. mustelus individuals from six litters, 90 C. obscurus individuals from 14 litters and 54 S. lewini individuals from 13 litters. Analysis in GERUD and COLONY revealed the presence of MP in all three species. Multiple paternities were observed in 67, 35 and 46% of the litters of M. mustelus, C. obscurus and S. lewini, with corresponding average sire size of 1.6, 1.4 and 2.0, respectively. The variation in the rate of MP among the three species is in accordance with previous studies whilst the comparatively high frequency of MP observed for M. mustelus, matches what has previously been reported for shark species demonstrating aggregation behaviour. (C) 2016 The Fisheries Society of the British Isles

Spaet, J. L. Y., Jabado, R. W., Henderson, A. C., Moore, A. B. M., & Berumen, M. L. (2015). Population Genetics of Four Heavily Exploited Shark Species around the Arabian Peninsula. *Ecology and Evolution, 5*(12), 2317-2332 https://doi.org/10.1002/ece3.1515

The northwestern Indian Ocean harbors a number of larger marine vertebrate taxa that warrant the investigation of genetic population structure given remarkable spatial heterogeneity in biological characteristics such as distribution, behavior, and morphology. Here, we investigate the genetic population structure of four commercially exploited shark species with different biological characteristics (Carcharhinus limbatus, Carcharhinus sorrah, Rhizoprionodon acutus, and Sphyrna lewini) between the Red Sea and all other water bodies surrounding the Arabian Peninsula. To assess intraspecific patterns of connectivity, we constructed statistical parsimony networks among haplotypes and estimated (1) population structure; and (2) time of most recent population expansion, based on mitochondrial control region DNA and a total of 20 microsatellites. Our analysis indicates that, even in smaller, less vagile shark species, there are no contemporary barriers to gene flow across the study region, while historical events, for example, Pleistocene glacial cycles, may have affected connectivity in C.sorrah and R.acutus. A parsimony network analysis provided evidence that Arabian S.lewini may represent a population segment that is distinct from other known stocks in the Indian Ocean, raising a new layer of conservation concern. Our results call for urgent regional cooperation to ensure the sustainable exploitation of sharks in the Arabian region.

Section III: Population Abundance

Arai, T., & Azri, A. (2019). Diversity, Occurrence and Conservation of Sharks in the Southern South China Sea. *PLoS One, 14*(3) https://doi.org/10.1371/journal.pone.0213864

Sharks constitute a vital sector of marine and estuarine nekton and are of great commercial importance all over the world. International concern over the fate of shark fisheries has grown recently. However, information concerning the species diversity, geographic distribution and life histories of sharks in the Indo-Pacific region is highly limited. Comprehensive research on the species composition, distribution and seasonal occurrence of sharks in the southern South China Sea (SSCS) was conducted for four years. A total of 4742 sharks belonging to 10 families and 28 species were recorded from 6 fishing ports in SSCS. The families recorded included Squalidae, Heterodontidae, Orectolobidae, Hemiscylliidae, Alopiidae, Scyliorhinidae, Triakidae, Hemigaleidae, Carcharhinidae and Sphyrnidae. Seventeen of 28 shark species were landed at various developmental stages from in the ranges of or even less than the length at birth and from newborn juveniles to fully-mature. The results suggest that these sharks were born just before fishing and landing, and reproductive-stage sharks were also fished and landed. In total, 15 species, four species and one species in 28 shark species were categorized as Near Threatened, Vulnerable and Endangered species, respectively, on the IUCN Red List. Sharks are not targeted by fisheries practices in the SSCS, but are caught as bycatch throughout the year in various developmental stages. Thus, current fisheries practices in the SSCS area might lead to further decline to critical levels and lead to extinction of some of species in the future. These results suggest that the need for gear selectivity of the commercial fishing gears in order to reduce mortality and to conserve shark stocks.

Brown, K. T., Seeto, J., Lal, M. M., & Miller, C. E. (2016). Discovery of an Important Aggregation Area for Endangered Scalloped Hammerhead Sharks, *Sphyrna Lewini*, in the Rewa River Estuary, Fiji Islands. *Pacific Conservation Biology, 22*(3), 242-248 https://doi.org/10.1071/PC14930

The scalloped hammerhead shark, Sphyrna lewini, is endangered throughout its global distribution. Management and protection of this species is challenging in many locations because of limited scientific data and the vulnerable life-history traits of the species. Our study investigated anecdotal evidence that the Rewa River estuary in Fiji serves as an important nursery area for this shark. Research findings indicated that the average length of both males (60.6 ± 6.78 cm, n = 31) and females (60.4 ± 6.85 cm, n = 51) was well within published size limits of juvenile S. lewini studied in other locations (range = 38.0–89.5 cm). On the basis of published reference points for umbilical scar status we postulate that the first captured juveniles were born in January of the study year. Stomach content analysis found the following prey items: Decapoda (represented by prawns and shrimps), Stomatopoda, anguilliformes and osteichthyes. Decapods were the most numerous prey item by both count (59.17% of total prey items) and weight (60.25% of total weight). Our study provides strong support that the Rewa River estuary is an important aggregation area for S. lewini in Fiji.

Furlong-Estrada, E., Tovar-Ávila, J., & Pérez-Jiménez, J. C. (2015). Resilience of Sphyrna Lewini, Rhizoprionodon Longurio, and Carcharhinus Falciformis at the Entrance to the Gulf of California after Three Decades of Exploitation. *British Library Online Contents* http://dx.doi.org/10.7773/cm.v41i1.2442

Given their biological characteristics, sharks exhibit low resilience and thereby are considered a fishery resource particularly vulnerable to overfishing. Yet, for several decades, three shark species (Sphyrna lewini, Rhizoprionodon longurio, and Carcharhinus falciformis) have contributed consistently to the catches of the artisanal shark fishery at the entrance to the Gulf of California, showing a certain degree of resilience. The aim of this study was to estimate their capacity to recover from disturbances, based on their rebound potential (r 2M), and analyze the factors that may be favoring their capacity to recover from fishing pressure in the region. Catch records, size composition of landings reported in previous studies and from undertaken surveys, as well as published information on life history parameters were used in the present analysis. Rhizoprionodon longurio showed high productivity (r 2M = 0.083) and thus high resilience, whereas C. falciformis and S. lewini presented medium productivities (r 2M = 0.053 and 0.062, respectively), but alternative scenarios to consider uncertainty in the life history parameters of C. falciformis and S. lewini placed them in the low productivity category. All species presented low productivity when the more conservative natural mortality (e.g., 1.25M) to achieve maximum sustainable yield was considered. Catches were dominated by juveniles of S. lewini, and by preadults and adults of R. longurio and C. falciformis during all the analyzed period; this and their consistent contribution to landings suggest apparent population stability. Such stability might be related to their biological productivity, elasticity, wide distribution range, migratory habits, and size segregation. Nonetheless, changes that occurred in this fishery over the last three decades may have also played an important role in the catch levels, particularly in the case of C. falciformis. Quantitative population assessments of these species to determine the optimum levels of extraction in the region are urgently needed.

Humber, F., Andriamahaino, E. T., Beriziny, T., Botosoamananto, R., Godley, B. J., Gough, C., . . . Broderick, A. C. (2017). Assessing the Small-Scale Shark Fishery of Madagascar through Community-Based Monitoring and Knowledge. *Fisheries Research, 186*, 131-143 https://doi.org/10.1016/j.fishres.2016.08.012

Over 90% of those employed in commercial capture fisheries work in the small-scale fisheries (SSF) sector and an estimated 97% of small scale fishers are found in least developed countries. However, the capacity for monitoring SSF globally is low and there is a paucity of data, in particular for remote areas within developing nations. The methods presented here demonstrate a low cost participatory approach for gathering data on small-scale fisheries, in particular for those that take place across remote areas. Community-based data collectors were trained to record biological and socioeconomic data on the traditional (non-motorised) shark fishery in the Toliara region of Madagascar over a six year period (2007–2012). An estimated 20 species of shark were recorded, of which 31% (n=3505) were Sphyrna lewini (scalloped hammerhead), a species listed by the IUCN as Endangered (IUCN, 2016). Although the number of sharks landed annually has not decreased during our survey period, there was a significant decrease in the average size of sharks caught. Despite multiple anecdotal reports of shark population declines, interviews and focus groups highlight the possibility that shark landings appear to have been maintained through changes in gear and increases in effort (eg. number of fishers, time spent fishing), which may mask a decline in shark populations. The numbers of sharks taken by the traditional fishery in our study region was estimated to be between 65,000 and 104,000year−1, whilst estimates using national export and import of dried shark fin from Madagascar, and shark length data in this study, put total landings between 78,000 and 471,851year−1. Reliable data on the total volume of sharks landed in Madagascar's waters is scarce, in particular from foreign industrial boats both directly targeting shark species and as bycatch in fisheries targeting other species. There is currently no legislation in place to

protect sharks from overexploitation in Madagascar and an urgent need to address the lack of shark fishery management across the traditional, artisanal and industrial fisheries.

Indian Ocean Tuna Commission. (2019). *Executive Summary : Status of the Indian Ocean Scalloped Hammerhead Shark (Spl: Sphyrna Lewini).* https://dx.doi.org/10.5281/zenodo.3263421

The current IUCN threat status of 'Endangered' applies to scalloped hammerhead sharks globally and specifically for the western Indian Ocean (Table 2). The ecological risk assessment (ERA) conducted for the Indian Ocean by the WPEB and SC in 2012 (IOTC–2012–SC15–INF10 Rev_1) consisted of a semi-quantitative risk assessment analysis to evaluate the resilience of shark species to the impact of a given fishery, by combining the biological productivity of the species and its susceptibility to each fishing gear type. Scalloped hammerhead shark received a low vulnerability ranking (No. 14) in the ERA rank for longline gear because it was estimated as one of the least productive shark species, but was also characterised by a lower susceptibility to longline gear. Scalloped hammerhead shark was estimated as the sixth most vulnerable shark species in the ERA ranking for purse seine gear, but with lower levels of vulnerability compared to longline gear, because the susceptibility was lower for purse seine gear. There is a paucity of information available on this species and this situation is not expected to improve in the short to medium term. Scalloped hammerhead sharks are commonly taken by a range of fisheries in the Indian Ocean. They are extremely vulnerable to gillnet fisheries. Furthermore, pups occupy shallow coastal nursery grounds, often heavily exploited by inshore fisheries. Because of their life history characteristics – they are relatively long lived (over 30 years), and have relativity few offspring (<31 pups each year), the scalloped hammerhead shark is vulnerable to overfishing. There is no quantitative stock assessment or basic fishery indicators currently available for scalloped hammerhead shark in the Indian Ocean therefore the stock status is uncertain

Liu, K. M., Chin, C. P., Chen, C. H., & Chang, J. H. (2015). Estimating Finite Rate of Population Increase for Sharks Based on Vital Parameters. *PLoS One, 10*(11), 20 https://doi.org/10.1371/journal.pone.0143008

The vital parameter data for 62 stocks, covering 38 species, collected from the literature, including parameters of age, growth, and reproduction, were log-transformed and analyzed using multivariate analyses. Three groups were identified and empirical equations were developed for each to describe the relationships between the predicted finite rates of population increase (lambda') and the vital parameters, maximum age (T-max), age at maturity (T-m), annual fecundity (f/R-c)), size at birth (L-b), size at maturity (L-m), and asymptotic length (L-infinity). Group (1) included species with slow growth rates (0.034 yr(-1) < k < 0.103 yr(-1)) and extended longevity (26 yr < T-max < 81 yr), e.g., shortfin mako Isurus oxyrinchus, dusky shark Carcharhinus obscurus, etc.; Group (2) included species with fast growth rates (0.103 yr(-1) < k < 0.358 yr(-1)) and short longevity (9 yr < T-max < 26 yr), e.g., starspotted smoothhound Mustelus manazo, gray smoothhound M. californicus, etc.; Group (3) included late maturing species (L-m/L-infinity >= 0.75) with moderate longevity (T-max < 29 yr), e.g., pelagic thresher Alopias pelagicus, sevengill shark Notorynchus cepedianus. The empirical equation for all data pooled was also developed. The lambda' values estimated by these empirical equations showed good agreement with those calculated using conventional demographic analysis. The predictability was further validated by an independent data set of three species. The empirical equations developed in this study not only reduce the uncertainties in estimation but also account for the difference in life history

among groups. This method therefore provides an efficient and effective approach to the implementation of precautionary shark management measures.

Miller, M. H., Carlson, J. K., Cooper, P. W., Kobayashi, D. R., Nammack, M., & Wilson, J. (2014). *Status Review Report: Scalloped Hammerhead Shark (Sphyrna Lewini).* Retrieved from https://repository.library.noaa.gov/view/noaa/17835

Updated March 2014: This status review report was conducted in response to a petition to list the scalloped hammerhead shark under the Endangered Species Act (ESA) (WildEarth Guardians and Friend of Animals to U.S. Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service (NMFS), August 14, 2011, "Petition to list the scalloped hammerhead shark (Sphyrna lewini) under the U.S. Endangered Species Act either worldwide or as one or more distinct population segments"). NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the August 14, 2011 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated a status review of the scalloped hammerhead shark. This status review report is comprised of two components: (1) the "Status Review" of the species, a document that compiles the best available information on the status of the scalloped hammerhead shark as required by the ESA, and (2) the "Assessment of Extinction Risk" for the species, a document that provides the methods and conclusions of the NMFS Extinction Risk Analysis (ERA) team on the current and future extinction risks of the scalloped hammerhead shark.

Pardo, S. A., Cooper, A. B., Reynolds, J. D., & Dulvy, N. K. (2018). Quantifying the Known Unknowns: Estimating Maximum Intrinsic Rate of Population Increase in the Face of Uncertainty. *Ices Journal of Marine Science, 75*(3), 953-963 https://doi.org/10.1093/icesjms/fsx220

Sensitivity to overfishing is often estimated using simple models that depend upon life history parameters, especially for species lacking detailed biological information. Yet, there has been little exploration of how uncertainty in life history parameters can influence demographic parameter estimates and therefore fisheries management options. We estimate the maximum intrinsic rate of population increase (rmax) for ten coastal carcharhiniform shark populations using an unstructured life history model that explicitly accounts for uncertainty in life history parameters. We evaluate how the two directly estimated parameters, age at maturity amat and annual reproductive output b, most influenced rmax estimates. Uncertainty in age at maturity values was low, but resulted in moderate uncertainty in rmax estimates. The model was sensitive to uncertainty in annual reproductive output for the least fecund species with fewer than 5 female offspring per year, which is not unusual for large elasmobranchs, marine mammals, and seabirds. Managers and policy makers should be careful to restrict mortality on species with very low annual reproductive output< 2 females per year. We recommend elasmobranch biologists to measure frequency distributions of litter sizes (rather than just a range) as well as improving estimates of natural mortality of data-poor elasmobranchs.

Penaherrera-Palma, C., van Putten, I., Karpievitch, Y. V., Frusher, S., Llerena-Martillo, Y., Hearn, A. R., & Semmens, J. M. (2018). Evaluating Abundance Trends of Iconic Species Using Local Ecological Knowledge. *Biological Conservation, 225*, 197-207 https://doi.org/10.1016/j.biocon.2018.07.004

Abundance is commonly used to assess the status of wildlife populations and their responses to changes in management frameworks. Monitoring abundance trends often requires long-term data collection programs, which are not always carried out. One alternative to scientific surveys is to utilize the local ecological knowledge (LEK), from people in continuous interactions with the environment. We developed a semi-quantitative approach to assess shark population trends by using the LEK of non-extractive resource users. We carried out structured interviews with dive guides regarding the abundance trends of six shark species in the Galapagos Marine Reserve (GMR) across decades since the 1980s. Based on dive guides' LEK, we developed a virtual abundance change (VAC) model to assess the changes in abundance across decades. Our VAC analysis showed a 50% decline in hammerhead sharks and 30% decline in whitetip reef sharks. Silky sharks and Galapagos sharks were perceived to suffer an initial decline by 25% and 30% then stabilized. Whale shark abundance did not appear to have changed. Finally, blacktip sharks showed an apparent recovery after a decline by 25%. Furthermore, our VAC results were comparatively similar to empirical datasets from the GMR and neighboring protected areas of the Eastern Tropical Pacific. Our study highlights the value of LEK in assessing the state of marine resources in data limited management regions. Our VAC method offers an alternative approach by which LEK can provide valuable insights into the historical trends of species abundance.

Pérez-Jiménez, J. C. (2014). Historical Records Reveal Potential Extirpation of Four Hammerhead Sharks (Sphyrna Spp.) in Mexican Pacific Waters. *Reviews in Fish Biology and Fisheries, 24*(2), 671-683 https://doi.org/10.1007/s11160-014-9353-y

Populations of hammerhead sharks (Sphyrna and Eusphyra) have declined in many regions of the world. Six of the eight hammerheads known to date are distributed in the Mexican Pacific: S. corona, S. lewini, S. media, S. mokarran, S. tiburo and S. zygaena. These species, with exception of S. corona, were abundant in the Gulf of California in 1960s. I analyze records from fishery-dependent and fishery-independent surveys, and records from ichthyological collections to determine the presence and frequency of hammerheads in the Mexican Pacific. The most frequent hammerheads in fishery-dependent and fishery-independent surveys were S. lewini and S. zygaena. It appears that S. media, S. mokarran and S. tiburo might have been extirpated from the Gulf of California. In the last two decades, records of S. mokarran (n = 61) were restricted to Central and Southern Mexican Pacific, and records of S. tiburo (n = 3) and S. media (n = 3) were restricted to the Southern region. Given the continued fishing pressure, inferred declines and the probable extirpation of populations, S. tiburo and S. media should be reassessed for the IUCN red list as Endangered or Critically Endangered. Sphyrna corona should be reassessed as Endangered or Critically Endangered, because it is endemic to the Eastern Pacific and recent records have been obtained only from Colombian waters. The Endangered status of S. mokarran is confirmed for this region.

Plumlee, J. D., Dance, K. M., Matich, P., Mohan, J. A., Richards, T. M., TinHan, T. C., . . . Wells, R. J. D. (2018). Community Structure of Elasmobranchs in Estuaries Along the Northwest Gulf of Mexico. *Estuarine Coastal and Shelf Science, 204*, 103-113 https://doi.org/10.1016/j.ecss.2018.02.023

Estuaries promote high levels of productivity and biodiversity by providing habitat for many biological communities due to their wide range of environmental conditions. Estuarine systems serve as nurseries, areas for parturition, and feeding grounds for elasmobranchs. However, estuaries face an array of anthropogenic pressures, including overfishing, altered flow regimes, pollution, and habitat destruction. Given the vulnerability of estuarine ecosystems, observing long-term changes in community structure is essential to understanding the effects of anthropogenic stressors. Elasmobranch community structure was analyzed among eight estuaries in the northwest Gulf of Mexico to evaluate spatial and temporal variability in species abundance and diversity using bi-annual fisheries independent gillnet survey data over three decades (1985-2014). Ten species comprised 99.4% of elasmobranchs caught which included 35.3% bull sharks (Carcharhinus leucas), 18.1% bonnetheads (Sphyrna tiburo), 17.0% cownose rays (Rhinoptera bonasus), 13.4% blacktip sharks (Carcharhinus limbatus), 5.9% Atlantic stingrays (Dasyatis sabina), 3.1% Atlantic sharpnose sharks (Rhizoprionodon terraenovae), 2.7% spinner sharks (Carcharhinus brevipinna), 2.1% scalloped hammerheads (Sphyrna lewini), 1.7% finetooth sharks (Carcharhinus isodon), and 0.7% lemon sharks (Negaprion brevirostris). During the study period, elasmobranch community structure changed among estuaries and among decades. Bull sharks, bonnetheads, cownose rays, blacktip sharks, and spinner sharks all increased in abundance during the study period, whereas finetooth sharks and lemon sharks decreased over time. Higher latitude estuaries were dominated by bull sharks while lower latitude estuaries were dominated by cownose rays. Salinity was the most important environmental variable in predicting individual elasmobranch species abundance (deviance explained: 14.4 +/- 6.5 SD), while temperature and depth also played a role in shaping community structure. Diversity was greatest in mid-latitudinal estuaries with spatially and temporally dynamic salinity regimes. As environmental change and human impacts persist across much of the world, understanding environmental drivers of community structure using long-term datasets will provide insight to how these changes influence coastal ecosystems, and enable more comprehensive and scale-independent models to be developed for the management and conservation of coastal ecotones.

Vierus, T., Gehrig, S., Brunnschweiler, J. M., Glaus, K., Zimmer, M., Marie, A. D., & Rico, C. (2018). Discovery of a Multispecies Shark Aggregation and Parturition Area in the Ba Estuary, Fiji Islands. *Ecology and Evolution, 8*(14), 7079-7093 https://doi.org/10.1002/ece3.4230

Population declines in shark species have been reported on local and global scales, with overfishing, habitat destruction and climate change posing severe threats. The lack of species-specific baseline data on ecology and distribution of many sharks, however, makes conservation measures challenging. Here, we present a fisheries-independent shark survey from the Fiji Islands, where scientific knowledge on locally occurring elasmobranchs is largely still lacking despite the location's role as a shark hotspot in the Pacific. Juvenile shark abundance in the fishing grounds of the Ba Estuary (north-western Viti Levu) was assessed with a gillnet- and longline-based survey from December 2015 to April 2016. A total of 103 juvenile sharks identified as blacktip Carcharhinus limbatus (n=57), scalloped hammerhead Sphyrna lewini (n=35), and great hammerhead Sphyrna mokarran (n=11) sharks were captured, tagged, and released. The condition of umbilical scars (68% open or semihealed), mean sizes of individuals (+/- SD) (C.limbatus: 66.5 +/- 3.8cm, S.lewini: 51.8 +/- 4.8cm, S.mokarran 77.4 +/- 2.8cm), and the presence of

these species over recent years (based on fishermen interviews), suggest that the Ba Estuary area is a critical habitat for multiple species that are classified as Near Threatened or Endangered. Specifically, the area likely acts as a parturition ground over the studied period, and potentially as a subsequent nursery area. We identified subareas of high abundance and found that temperature, salinity and depth acted as small-scale environmental drivers of shark abundance. The data suggests a tendency for species-specific spatial use, both horizontally (i.e., between sampling areas) and vertically (i.e., across the water column). These results enhance the understanding of shark ecology in Fiji and provide a scientific basis for the implementation of local conservation strategies that contribute to the protection of these threatened species.

Wells, R. J. D., TinHan, T. C., Dance, M. A., Drymon, J. M., Falterman, B., Ajemian, M. J., . . . McKinney, J. A. (2018). Movement, Behavior, and Habitat Use of a Marine Apex Predator, the Scalloped Hammerhead. *Frontiers in Marine Science, 5*, 14 https://doi.org/10.3389/fmars.2018.00321

Conservation and management efforts of marine apex predators are more reliable when information on movement and habitat use patterns are known. The scalloped hammerhead (Sphyma lewini) was the first shark species to be protected under the U.S. Endangered Species Act and has life history characteristics that make this species particularly at risk for local depletion. Consequently, the goal of this study was to better understand the movement dynamics of this species in the Gulf of Mexico (GOM) where discards through the longline fishery can be substantial. A total of 33 scalloped hammerheads were tagged with fin mounted satellite tags and tracked for an average of 146 days (ranging from 5 to 479 days) to examine horizontal movements and quantify space use. Scalloped hammerheads showed a wide range of movements throughout the GOM continental shelf with limited long-distance dispersal and females displayed a shelf-edge association relative to more mid-shelf use by males. A generalized additive model was developed to identify habitat suitability for scalloped hammerheads in the GOM, while state-space modeling was used to examine movement behaviors. Model results highlighted the use of continental shelf waters with high occurrence at close proximities to both artificial and hard-bottom habitat combined with low chlorophyll a concentrations (similar to 0-4 mg m(-3)) and moderate salinities (33-35.5). Habitat suitability for scalloped hammerheads was predicted to be high on the mid to outer continental shelf inside the 200 m isobath and state-space model results suggest area-restricted behavior was most common relative to transient behavior. Findings from this study provide important information on movement of this species in the GOM and highlight their restricted use of continental shelf habitat and resident behavior that will need to be incorporated in future stock assessments and extinction risk analyses.

Zanella, I., & Lopez-Garro, A. (2015). Abundance, Reproduction and Length of Scalloped Hammerhead Shark Sphyrna Lewini (Carcharhiniformes: Sphyrnidae) in the Artisanal Fishery in Golfo Dulce, Pacific of Costa Rica. *Revista De Biologia Tropical, 63*, 307-317 Retrieved from https://www.scielo.sa.cr/scielo.php?script=sci_abstract&pid=S0034-77442015000500307&lng=en&nrm=iso

Incidental catch of S. lewini by artisanal fishermen in Golfo Dulce, Costa Rica, suggest that this could be one of the coastal locations used by the species. This study aims to characterize the scalloped hammerhead shark population in Golfo Dulce, in order to best guide management actions for the conservation and sustainable use of the species. Fisheries-dependent biological data (size-TL, sex, reproductive status) were gathered for S. lewini between May 2010 and May 2011 in the communities

of Puerto Jimenez and Pavones, Golfo Dulce during artisanal fishing trips. Catch per unit effort (CPUE) throughout the year was also estimated from catch data. We sampled a total of 315 sharks. Mean total length was estimated at 74.3 +/- 17.4cm. Both pups and juveniles were reported, which presented a male: female ratio of 1: 1.2 ($p>0.05$). Total length and relative abundance of S. lewini had opposite tendencies, with the smallest TL (64cm) recorded during July-August, when CPUE was highest. (0.0075). Temporary closures from June to August are therefore recommended at areas of highest reported catch (Pique Fijo, Los Bajos y La Cienaga), in order to protect newly born S. lewini, and promote the sustainability of the species in the ETPS Closures should be complemented with a long-term study that can further clarify whether Golfo Dulce is a nursery area for S. lewini.

Zanella, I., Lopez-Garro, A., McComb-Kobza, D. M., Golfin-Duarte, G., Perez-Montero, M., & Morales, J. (2016). First Record of Young-of-the-Year Scalloped Hammerhead Shark, Sphyrna Lewini (Carcharhiniformes: Sphyrnidae) from Isla Del Coco National Park, Costa Rica. *Revista De Biologia Tropical, 64*, Retrieved from https://revistas.ucr.ac.cr/index.php/rbt/article/view/23448

The Scalloped hammerhead shark, Sphyrna lewini is a coastal and pelagic circumglobal species that resides within coastal warm temperate and tropical seas. Sphyrna lewini exhibits strong intraspecific segregation: neonates and young-of-the-year spend the first part of life in coastal inshore waters (nursery grounds), while adults migrate offshore, returning to protected nursery habitats for mating and pupping. On December 3, 2014, at approximately 19: 00 hr, four young-of-the-year S. lewini were caught with hand line in Wafer Bay, Isla del Coco, Costa Rica (5 degrees 32'42.4 '' N - 87 degrees 03'45.3 '' W). A total of three males (total length (TL): 73, 73, 76 cm) and one female (TL: 75 cm) were recorded. The presence of these individuals at Isla del Coco suggests that a pregnant female gave birth in or near Wafer Bay, which may be a nursery ground for S. lewini. We recommend further study to evaluate the presence and movements of young-of-the-year and juvenile S. lewini in Wafer Bay to determine if this was an isolated incident or if the bay is a nursery ground for S. lewini.

Section IV: Threats

Bergés-Tiznado, M. E., Márquez-Farías, F., Lara-Mendoza, R. E., Torres-Rojas, Y. E., Galván-Magaña, F., Bojórquez-Leyva, H., & Páez-Osuna, F. (2015). Mercury and Selenium in Muscle and Target Organs of Scalloped Hammerhead Sharks Sphyrna Lewini of the Se Gulf of California: Dietary Intake, Molar Ratios, Loads, and Human Health Risks. *Archives of Environmental Contamination and Toxicology, 69*(4), 440-452 https://doi.org/10.1007/s00244-015-0226-8

Selenium and mercury were evaluated in muscle, liver, kidney, brain, and the stomach contents of juvenile scalloped hammerhead shark Sphyrna lewini. Se:Hg molar ratios were calculated. The average Hg levels in muscle ranged from 0.12 to 1.17 μg/g (wet weight); Hg was <0.39 μg/g in liver and kidneys and <0.19 μg/g in brain. The lowest value of Se was found in muscle (0.4 μg/g) and the highest in kidney (26.7 μg/g). An excess of Se over Hg was found, with Se:Hg molar ratios >1. Correlations were found for Hg in muscle with size, age, and weight, and also for Hg in liver with size, age, and weight. Hg in muscle was significantly positive correlated to Hg in brain as well as Hg in liver was correlated to Hg in kidney. The highest Hg in preys was for carangid fishes; scombrid and carangid fishes contributed with the highest Se levels. Results suggest that more than 98 % of the total Hg and 62 % of Se end up in muscle and might be affected by factors, such as geographical area, age, size, and feeding habits. The muscle of S. lewini should be consumed by people cautiously so as not to exceed the recommended intake per week.

Bezerra, N. P. A., Travassos, P., & Hazin, F. H. V. (2016). Vulnerability to Longline Fisheries of Three Hammerhead Shark Sphyrna Species in the South-Western and Equatorial Atlantic Ocean. *Journal of Fish Biology, 89*(2), 1419-1433 https://doi.org/10.1111/jfb.13062

Catch and effort data from 29 418 longline sets from Brazilian tuna longline vessels operating in the south-western and equatorial Atlantic Ocean between 2004 and 2011 were analysed to investigate the distribution, catch rate and size of three species of hammerhead sharks (Sphyrna lewini, Sphyrna mokarran and Sphyrna zygaena). During that period, 6172 hammerhead sharks were caught. Among the elasmobranchs, the highest percentage of hammerhead sharks were caught in 2007, when they accounted for 3·90% of the group, while the lowest value of 0·40% was recorded in 2010. In general, the spatial distribution of the mean catch per unit effort (CPUE) by years and quarters showed a trend of higher catches near the equatorial region and in southern Brazil. The nominal mean CPUE was 0·12 Sphyrna spp. 1000−1 hooks, with the highest value being recorded in 2007 (0·30 Sphyrna spp. 1000−1 hooks). The standardized yearly CPUE estimated by a generalized linear model assuming a zero inflated negative binomial (ZINB) distribution were not much different from nominal values. Of the 205 sexed specimens, 117 were females and 88 were males, resulting in a sex ratio with a predominance of females (1·30:1·00), although not statistically significant. The total length of females ranged from 1200 to 2800 mm and of males from 1100 to 3100 mm. Juvenile hammerhead sharks represented 82 and 54% of the sexed female and male specimens, respectively.

Boldrocchi, G., Monticelli, D., Omar, Y. M., & Bettinetti, R. (2019). Trace Elements and Pops in Two Commercial Shark Species from Djibouti: Implications for Human Exposure. *Science of the Total Environment, 669*, 637-648 https://doi.org/10.1016/j.scitotenv.2019.03.122

Within Djibouti (Gulf of Aden), the scalloped hammerhead shark (Sphyrna lewini) and milk shark (Rhizoprionodon acutus) are important components of the artisanal fishery and they are caught to be exported or sold for local consumption. However, little scientific information exists on the contamination load of these species in this area of the world. With global populations of elasmobranchs in decline, understanding the extent of contaminant exposure is critical to future conservation as well as to assess the health risks for consumers of these species. The contaminants analyzed in this study comprised PCB, DDT and trace elements in livers, muscles and fins of both hammerhead sharks and milk sharks. The overall organochlorine compounds (OCs) and trace elements concentrations were similar among the two sharks' species and the pattern of PCB and DDT tissue distribution showed the highest burdens in livers compared with muscles and fins. However, the different accumulation profiles of OCs among shark species suggest species-specific accumulation of these contaminants. The p,p'DDE/∑DDT ratios were equal or slightly higher than the critic value of 0.6, suggesting possible recent inputs of technical DDT in the area. Concentration of trace elements from this study were generally comparable to those found in sharks from other areas of the world and, highlight the wide variation in metal concentrations between species, individuals and tissues. As far as Hg is concerned, scalloped hammerhead sharks showed higher accumulation in muscles compared with milk sharks. Both species showed elevated concentration of Se, which might be related to high Hg levels since Se inhibits Hg toxicity. The potential cancer risk for PCB, Cd, Ni, Cr and As fell within the range of 10−6–10−4, suggesting some concerns for the overall contamination levels in both species. Indeed, consuming of fish involves a mixture of all analyzed elements, and therefore, some potential risk might arise from regularly consuming these species.

Bornatowski, H., Braga, R. R., & Vitule, J. R. S. (2014). Threats to Sharks in a Developing Country: The Need for Effective Simple Conservation Measures. *Natureza & Conservação, 12*(1), 11-18 https://doi.org/10.4322/natcon.2014.003

Reductions of shark populations produce negative ecological and economic consequences. Overfishing is the primary threat to these reductions; however, two other indirect problems can be mentioned as threats to sharks populations: shark meat mislabeling, and shark attacks. In this study, we use Brazil as an example to focus on these three critical problems related to shark conservation: the lack of proper, specific identification of landed species in the industrial and artisanal fisheries; shark attacks; and mislabeling in markets. We discuss these situations, highlighting brief examples and conservation barriers. The main goal is to present these problems and provide simple, effective solutions. On the fisheries side, the solution lies in having trained personnel at specific landing ports. Implementation of this practice would also aid in the solution to the mislabeling of shark meat. However, whenever this does not occur, supermarkets or any other final seller should be held legally responsible for the identification. At this stage, genetic techniques such as DNA barcoding must be used. Regarding the shark attack problem, the only truly efficient solution with no indirect effects is education and taking the matter to society, rather than waiting until there is a shark attack incident. The government needs to invest more funds on educational awareness programs and research to avoid encounters with sharks. We must ensure that the society does not see sharks as villains, but instead as key elements in maintaining the ecosystem services that are so valuable to human well-being.

Chuang, P. S., Hung, T. C., Chang, H. A., Huang, C. K., & Shiao, J. C. (2016). The Species and Origin of Shark Fins in Taiwan's Fishing Ports, Markets, and Customs Detention: A DNA Barcoding Analysis. *PLoS One, 11*(1), 13 https://doi.org/10.1371/journal.pone.0147290

The increasing consumption of shark products, along with the shark's fishing vulnerabilities, has led to the decrease in certain shark populations. In this study we used a DNA barcoding method to identify the species of shark landings at fishing ports, shark fin products in retail stores, and shark fins detained by Taiwan customs. In total we identified 23, 24, and 14 species from 231 fishing landings, 316 fin products, and 113 detained shark fins, respectively. All the three sample sources were dominated by Prionace glauca, which accounted for more than 30% of the collected samples. Over 60% of the species identified in the fin products also appeared in the port landings, suggesting the domestic-dominance of shark fin products in Taiwan. However, international trade also contributes a certain proportion of the fin product markets, as four species identified from the shark fin products are not found in Taiwan's waters, and some domestic-available species were also found in the customs-detained sample. In addition to the species identification, we also found geographical differentiation in the cox1 gene of the common thresher sharks (Alopias vulpinus), the pelagic thresher shark (A. pelagicus), the smooth hammerhead shark (Sphyrna zygaena), and the scalloped hammerhead shark (S. lewini). This result might allow fishing authorities to more effectively trace the origins as well as enforce the management and conservation of these sharks.

Doherty, P. D., Alfaro-Shigueto, J., Hodgson, D. J., Mangel, J. C., Witt, M. J., & Godley, B. J. (2014). Big Catch, Little Sharks: Insight into Peruvian Small-Scale Longline Fisheries. *Ecology and Evolution, 4*(12), 2375-2383 https://doi.org/10.1002/ece3.1104

Shark take, driven by vast demand for meat and fins, is increasing. We set out to gain insights into the impact of small-scale longline fisheries in Peru. Onboard observers were used to document catch from 145 longline fishing trips (1668 fishing days) originating from Ilo, southern Peru. Fishing effort is divided into two seasons: targeting dolphinfish (Coryphaena hippurus; December to February) and sharks (March to November). A total of 16,610 sharks were observed caught, with 11,166 identified to species level. Of these, 70.6% were blue sharks (Prionace glauca), 28.4% short-fin mako sharks (Isurus oxyrinchus), and 1% were other species (including thresher (Alopias vulpinus), hammerhead (Sphyrna zygaena), porbeagle (Lamnus nasus), and other Carcharhinidae species (Carcharhinus brachyurus, Carcharhinus falciformis, Galeorhinus galeus). Mean ± SD catch per unit effort of 33.6 ± 10.9 sharks per 1000 hooks was calculated for the shark season and 1.9 ± 3.1 sharks per 1000 hooks were caught in the dolphinfish season. An average of 83.7% of sharks caught (74.7% blue sharks; 93.3% mako sharks) were deemed sexually immature and under the legal minimum landing size, which for species exhibiting k-selected life history traits can result in susceptibility to over exploitation. As these growing fisheries operate along the entire Peruvian coast and may catch millions of sharks per annum, we conclude that their continued expansion, along with ineffective legislative approaches resulting in removal of immature individuals, has the potential to threaten the sustainability of the fishery, its target species, and ecosystem. There is a need for additional monitoring and research to inform novel management strategies for sharks while maintaining fisher livelihoods.

Duffy, L. M., Lennert-Cody, C. E., Olson, R. J., Minte-Vera, C. V., & Griffiths, S. P. (2019). Assessing Vulnerability of Bycatch Species in the Tuna Purse-Seine Fisheries of the Eastern Pacific Ocean. *Fisheries Research, 219*, 105316 https://doi.org/10.1016/j.fishres.2019.105316

Ecological risk assessment (ERA), including Productivity-Susceptibility Analysis (PSA), is becoming increasingly used to assess the relative vulnerability of data-limited non-target species to the impacts by fishing. PSA was developed for the eastern Pacific Ocean (EPO) tuna purse-seine fishery to assess the vulnerability of incidentally-caught species for three set types, “dolphin sets”, “unassociated sets” and “floating-object sets”, during 2005–2013. Because of operational differences between these set types, susceptibility values were combined for each species across the three set types to produce an overall fleet-wide susceptibility estimate. Vulnerability was highest for elasmobranchs, namely the giant manta ray, bigeye and pelagic thresher sharks, smooth and scalloped hammerhead sharks, and silky shark. Billfishes, dolphins, other rays, ocean sunfish, and yellowfin and bigeye tunas were classified as moderately vulnerable while the remaining species, all teleosts, had the lowest vulnerability scores. This purse-seine fleet-wide PSA identified potentially vulnerable species that can be compared with PSAs for other fisheries operating in the EPO, once detailed catch information becomes available for those fisheries. Such information can assist managers with prioritising fishery- and species-specific research programs and/or mitigation measures.

Enzenauer, M. P., Deacy, B. M., & Carlson, J. K. (2015). Characterization of the Shark Bottom Longline Fishery, National Marine Fisheries Technical Memorandum NMFS-SEFSC-677 2014. https://doi.org/10.7289/V58C9T6D

"Observations of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (e.g. Hale et al. 2012 and references therein). Currently about 198 U.S. fishers are permitted to target sharks (excluding dogfish) in the Atlantic Ocean and Gulf of Mexico, and an additional 252 fishers are permitted to land sharks incidentally. Amendments to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan implemented a shark research fishery, which allows NMFS to select a limited number of commercial shark vessels on an annual basis to collect life history data and catch data for future stock assessments (NMFS, 2007). Specifically, only commercial shark fishers participating in the research fishery are allowed to land sandbar sharks, Carcharhinus plumbeus, and must carry an observer on 100% of all trips (compared to a target coverage level of 5-10% outside the research fishery). Outside the research fishery, fishers are permitted to land 36 nonsandbar large coastal sharks per trip (including blacktip shark, Carcharhinus limbatus, bull shark, Carcharhinus leucas, lemon shark, Negaprion brevirostris, nurse shark, Ginglymostoma cirratum, silky shark, Carcharhinus falciformis, spinner shark, Carcharhinus brevipinna, tiger shark, Galeocerdo cuvier, great hammerhead shark, Sphyrna mokarran, scalloped hammerhead shark, Sphyrna lewini, and smooth hammerhead shark, Sphyrna zygaena). Herein, we report on fishing activities in the bottom longline fishery for the 2014 fishing season, including coverage of the 2014 Shark Research Fishery"

Enzenauer, M. P., Deacy, B. M., & Carlson, J. K. (2016). Characterization of the Shark Bottom Longline Fishery, National Marine Fisheries Service Technical memorandum NMFS-SEFSC-677 2015. https://doi.org/10.7289/V52J68WG

Observations of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (Morgan et al. 2009, Enzenauer et al. 2015 and references therein). Currently about 210 U.S. fishers are permitted to target sharks (excluding dogfish) in the Atlantic Ocean and Gulf of Mexico, and an additional 254 fishers are permitted to land sharks incidentally. Amendments to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan implemented a shark research fishery, which allows NMFS to select a limited number of commercial shark vessels on an annual basis to collect life history data and catch data for future stock assessments (NMFS, 2007). Specifically, only commercial shark fishers participating in the research fishery are allowed to land sandbar sharks, Carcharhinus Plumbeus, and must carry an observer on 100% of all trips (compared to a target coverage level of 5-10% outside the research fishery). Outside the research fishery, fishers are permitted to land other large coastal sharks (e.g. blacktip shark, Carcharhinus limbatus, and bull shark, Carcharhinus leucas,). Herein, we report on observed fishing activities in the shark bottom longline fishery for the 2015 fishing season, including coverage of the 2015 Shark Research Fishery

Gallagher, A. J., Orbesen, E. S., Hammerschlag, N., & Serafy, J. E. (2014). Vulnerability of Oceanic Sharks as Pelagic Longline Bycatch. *Global Ecology and Conservation, 1*, 50-59 https://doi.org/10.1016/j.gecco.2014.06.003

Bycatch (the unintentional catch of non-target species or sizes) is consistently ranked as one of the greatest threats to marine fish populations; yet species-specific rates of bycatch survival are rarely considered in risk assessments. Regulations often require that bycatch of threatened species be released; but, if animals are already dead, their release serves no conservation purpose. We examined the survival of 12 shark species caught as bycatch in the US Atlantic pelagic longline fishery. Shark survival was evaluated in relation to fishery target (swordfish versus tuna) and four operational, environmental, and biological variables to evaluate the underlying mechanisms affecting mortality. Survival estimates ranged from 33% (night shark) to 97% (tiger shark) with seven of the 12 species being significantly affected by at least one variable. We placed our survival results within a framework that assessed each species' relative vulnerability by integrating survival estimates with reproductive potential and found that the bigeye thresher, dusky, night, and scalloped hammerhead shark exhibited the highest vulnerabilities to bycatch. We suggest that considering ecological and biological traits of species shows promise for designing effective conservation measures, whereas techniques that reduce fisheries interactions in the first place may be the best strategy for highly vulnerable species.

Gulak, S. J. B., de Ron Santiago, A. J., & Carlson, J. K. (2015). Hooking Mortality of Scalloped Hammerhead Sphyrna Lewini and Great Hammerhead Sphyrna Mokarran Sharks Caught on Bottom Longlines. *African Journal of Marine Science, 37*(2), 267-273 https://doi.org/10.2989/1814232X.2015.1026842

The scalloped hammerhead Sphyrna lewini and the great hammerhead S. mokarran are typically caught as bycatch in a variety of fisheries and are listed as globally Endangered by the International Union for the Conservation of Nature. Due to very high at-vessel mortality for these species, research is needed on fishing methods to reduce mortality for longline-captured sharks. A series of fishing experiments were

conducted employing hook timers and temperature?depth recorders on contracted commercial vessels fishing with bottom-longline gear to assess factors related to mortality. A total of 273 sets were deployed with 54 485 hook timers. Scalloped and great hammerheads had at-vessel mortality rates of 62.9% and 56.0%, respectively. Median hooking times for scalloped and great hammerheads were 3.5?h and 3.4?h, respectively, and 50% mortality was predicted at 3.5?h and 3.8?h. When these data are considered for potential management strategies to reduce the mortality of hammerhead sharks, a limitation on gear soak time would probably improve hammerhead shark survivorship. However, it may prove to be difficult for a fishery to remain economically viable if the soak time is limited to less than the median hooking time for the target species. Additional management options, such as time/area closures, may need to be explored to reduce bycatch mortality of scalloped and great hammerheads.

Jaiteh, V. F., Allen, S. J., Meeuwig, J. J., & Loneragan, N. R. (2014). Combining in-Trawl Video with Observer Coverage Improves Understanding of Protected and Vulnerable Species by-Catch in Trawl Fisheries. *Marine and Freshwater Research, 65*(9), 830-837 https://doi.org/10.1071/MF13130

Assessments of incidental wildlife mortality resulting from fishing rarely account for unobserved by-catch. We assessed by-catch of protected and vulnerable wildlife species in an Australian trawl fishery by comparing in-trawl video footage with data collected by an on-board observer. Data were obtained from 44 commercial trawls with two different by-catch reduction devices (BRDs). Eighty-six individuals from six major taxa (dolphins, sharks, rays, sea snakes, turtles and sygnathids) were documented from video analysis, including the endangered scalloped hammerhead shark (Sphyrna lewini) and the critically endangered green sawfish (Pristis zijsron). On the basis of the 2008–2009 fishing effort of 4149 trawls and scaling from these results, we estimated the annual catch of protected and vulnerable species (± 1 s.e.) at 8109 ± 910 individuals. Only 34% of by-catch was expelled through the BRDs. Independent observer data for the 44 trawls showed that 77% of the landed by-catch from these taxa were dead when discarded. The results indicate that unaccounted by-catch in trawl fisheries can be substantial, and that current methods of recording by-catch on-board vessels are likely to underestimate total fishing mortality. We recommend gear modifications and their validation through dedicated observer coverage, combined with in-trawl video camera deployments to improve current approaches to by-catch mitigation.

Lopez-Garro, A., & Zanella, I. (2015). Sharks and Rays Caught by Artisanal Bottom Line in Golfo Dulce, Costa Rica. *Revista De Biologia Tropical, 63*, 183-198 Retrieved from https://revistas.ucr.ac.cr/index.php/rbt/article/view/23102/23359

Since May 2010 until May 2011 biological and fishery information regarding 67 artisanal fishing operations were collected in different areas of Golfo Dulce. A total of 30 (44.8%) onboard operations and 37 (55.2%) landings were observed. During onboard operations, a total of 872 fish were caught: 345 (39.6%) were sharks (Sphyrnidae, Carcharhinidae, Heterodontidae, Ginglymostomatidae and Triakidae), 228 (26.1%) "bait" fish (Aridae), 112 (13.1%) rays (Dasyatidae, Myliobatidae, Rhinobatidae and Mobulidae) and 111 (12.7%) commercial fish (Lutjanidae, Serranidae Sciaenidae). The capture condition (dead or alive), the low commercial value and the availability of fishermen, allowed us to release 65 sharks and 111 rays, all of them were alive and without hooks. Of these 75.7% were stingrays (D. longa), 12.6% eagle ray (A. narinari), 5.4% cownose rays (R. steindachneri), 5.4% guitar fish (R. leucorhynchus), the spoited ray 2.7% (U. chilenis), 0.9% butterfly ray (G. marmorata), and 0.9% mobula (Mobula sp.). The

CPUE rate shows that the sharks and rays contributed more than 50% of the total catch of fishing operations. However, the months when the fishermen caught more sharks, the rays were not abundant. July and August were the months with the highest shark CPUE, while January-February were the months with the highest ray catches. Regarding the 37 landings observations, a total of 264 sharks were analyzed, being the scalloped hammerhead shark the most abundant (S. lewini, n= 163), with 61.7%, followed by the common soothhound shark (M. lunulatus, n= 48) (18.2%), the blacktip shark (C. limbatus, n= 27) (10.2%) the pacific sharpnose shark (R. longurio, n= 24) (9.1%), whitenose shark (0.4%) (Nasolamia velox, n= 1) and the bonnethead shark (0.4%) (Sphyrna tiburo, n= 1). The fusion of biological and fishery data from onboard observations and landings made it possible to analyze a total 609 sharks belonging to ten species. Of these, S. lewini represented more than 51.8% of total sharks analyzed; M. lunulatus, 23.5% R. longurio, 13.8% and C. limbatus, 8.9%. Other species G. cirratum, G. cuvier, N. velox, shovel head shark (S. tiburo) and the horn shark H. mexicanus were very sporadic since they contributed only 2.0% of the total. Analyses of length of S. lewini showed that they are mostly juveniles (74.31 +/- 17.4cm). Similar situation was found with individuals of R. longurio, M. lunulatus and C. limbatus whose mean total lengths were of 65.22 +/- 14.04cm, 94.08 +/- 23.64cm 4.44cm respectively 76.65cm.

Lyons, K., & Adams, D. H. (2015). Maternal Offloading of Organochlorine Contaminants in the Yolk-Sac Placental Scalloped Hammerhead Shark (Sphyrna Lewini). *Ecotoxicology, 24*(3), 553-562 https://doi.org/10.1007/s10646-014-1403-7

Elasmobranchs are a group of animals that typically occupy upper trophic levels in food webs and have a propensity to accumulate high contaminant concentrations. To date, few studies have investigated maternal offloading processes in sharks, despite the fact that this process represents a substantial source of exposure for young sharks and is a significant pathway for contaminant redistribution within marine ecosystems. Comparable to mammalian systems, scalloped hammerhead sharks (Sphyrna lewini) utilize a yolk-sac placental strategy to nourish young in utero, which may allow females to transfer contaminants to young. Organic contaminants (PCBs and chlorinated pesticides) were measured in livers of both females and males from several age classes that were collected from U.S. Atlantic waters, including two near-term pregnant females and their embryos. Adult female hammerheads (n = 3) were found to have lower levels of PCBs compared to the younger, adult male (mean +/- SD, 11.1 +/- 1.0 vs. 22.8 mu g g(-1) lw), but had substantially higher concentrations of pesticides (4.1 +/- 0.9 vs. 1.9 mu g g(-1) lw). Embryos from the two litters (n = 36) had similar levels of summed organic contaminant concentrations (4.6 +/- 0.9 mu g g(-1) lw) and pregnant females were estimated to offload approximately 0.03-2.3 % of their hepatic contaminant load to offspring. While the potential health impacts of these transferred contaminants is unknown, this is the first study to demonstrate that scalloped hammerheads are exposed to a substantial amount of contaminants prior to birth and document maternal offloading of organochlorines in a pseudo-placental shark species. Therefore, future research should continue to investigate the potential adverse effects these contaminants have on elasmobranch physiology.

Mathers, A. N., Deacy, B. M., & Carlson, J. K. (2015). Catch and Bycatch in U.S. Southeast Gillnet Fisheries, National Marine Fisheries Techical Memorandum NMFS-SEFSC-675 2014. https://doi.org/10.7289/V54Q7RXF

"The Southeast Gillnet Observer Program has adapted to the changes of the Florida- Georgia shark gillnet fishery since the program began in 1993 (e.g. Carlson and Bethea 2007 and references therein,

Mathers et al. 2014). There are currently about 500 total directed and incidental shark permits issued in the US Atlantic and Gulf of Mexico, while the number of gillnet fishers changes from year to year. Gillnet effort targeting large coastal (LCS) and small coastal (SCS) sharks, has declined in recent years as a result of Amendments 2 and 3 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2007, 2010). Fishers have consequently increased effort targeting finfish, including Spanish mackerel Scomberomorus maculatus, king mackerel Scomberomorus cavalla, and bluefish Pomatomus saltatrix, with varying types of gillnet gear. However, a small amount of shark targeted gillnet effort continues to be observed. The Southeast Gillnet Observer Program, in its continuing efforts to adapt to the fishery, currently covers anchored (sink and stab), strike, or drift gillnet fishing regardless of target by vessels that fish from Florida to North Carolina and the Gulf of Mexico year-round. Herein, we summarize fishing effort and catch and bycatch in these fisheries during January 2014 - December 2014, collectively referred to as '2014'

Mathers, A. N., Deacy, B. M., & Carlson, J. K. (2017). Catch and Bycatch in U.S. Southeast Gillnet Fisheries, National Marine Fisheries Techical Memorandum NMFS-SEFSC-713 2016. https://doi.org/10.7289/V5/TM-SEFSC-713

"The Southeast Gillnet Observer Program has adapted to the changes of the Florida-Georgia shark gillnet fishery since the program began in 1993 (e.g. Carlson and Bethea 2007 and references therein, Mathers et al. 2015). There are currently about 500 total directed and incidental shark permits issued for the southeastern U.S. Atlantic coast and Gulf of Mexico, while the number of gillnet fishers changes from year to year. Gillnet effort targeting large coastal (LCS) and small coastal (SCS) sharks declined as a result of Amendments 2 and 3 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2007, 2010). LCS and SCS targeted gillnet effort has continued to decline in the last five years, such that it has become almost nonexistent. Fishers have consequently increased effort targeting finfish, including Spanish mackerel Scomberomorus maculatus, king mackerel Scomberomorus cavalla, and bluefish Pomatomus saltatrix, with varying types of gillnet gear. However, a small amount of shark targeted gillnet effort continues to be observed. The Southeast Gillnet Observer Program, in its continuing efforts to adapt to the fishery, currently covers anchored (sink and stab), strike, or drift gillnet fishing, regardless of target, by vessels that fish year-round from Florida to North Carolina and the Gulf of Mexico. Herein, we summarize fishing effort and catch and bycatch in these fisheries during January 2016 - December 2016, collectively referred to as '2016'

Mathers, A. N., Deacy, B. M., Moncrief-Cox, H. E., & Carlson, J. K. (2018). Characterization of the Shark Bottom Longline Fishery, National Marine Fisheries Technical Memorandum NMFS-SEFSC-727 2017. https://doi.org/10.25923/f1n6-r841

Observations of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (Morgan et al. 2009, Mathers et al. 2017 and references therein). Currently about 219 U.S. fishers are permitted to target sharks in the Atlantic Ocean and Gulf of Mexico, and an additional 264 fishers are permitted to land sharks incidentally. Amendments to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan implemented a shark research fishery, which allows NMFS to select a limited number of commercial shark vessels on an annual basis to collect life history data and catch data for future stock assessments (NMFS, 2007). Specifically, only commercial shark fishers participating in the research fishery are allowed to land sandbar sharks, Carcharhinus plumbeus, and must carry an observer on 100% of all trips (compared to a target coverage

level of 5-10% outside the research fishery). Outside the research fishery, fishers are permitted to land other large coastal sharks (e.g. blacktip shark, Carcharhinus limbatus, and bull shark, Carcharhinus leucas). Herein, we report on observed fishing activities in the shark bottom longline fishery for the 2017 fishing season, including coverage of the 2017 Shark Research Fishery.

National Marine Fisheries Service. (2014). 2014 Shark Finning Report to Congress. Retrieved from https://repository.library.noaa.gov/view/noaa/15644

This Report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar year 2013 to implement the Shark Finning Prohibition Act and more recent shark conservation legislation. The 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction. The 2000 Shark Finning Prohibition Act requires NMFS to promulgate regulations to implement its provisions, initiate discussion with other nations to develop international agreements on shark finning and data collection, provide Congress with annual reports describing efforts to carry out the Shark Finning Prohibition Act, and establish research programs.

National Marine Fisheries Service. (2015). 2015 Shark Finning Report to Congress. Retrieved from https://repository.library.noaa.gov/view/noaa/15645

This report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar year 2014 to implement the Shark Finning Prohibition Act and more recent shark conservation legislation. The 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction. The 2000 Shark Finning Prohibition Act requires NMFS to promulgate regulations to implement its provisions, initiate discussion with other nations to develop international agreements on shark finning and data collection, provide Congress with annual reports describing efforts to carry out the Shark Finning Prohibition Act, and establish research programs.

National Marine Fisheries Service. (2017). 2016 Shark Finning Report to Congress. Retrieved from https://repository.library.noaa.gov/view/noaa/17060

This report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar year 2015 to implement the Shark Finning Prohibition Act and more recent shark conservation legislation. The 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction. The 2000 Shark Finning Prohibition Act requires NMFS to promulgate regulations to implement its provisions, initiate discussion with other nations to develop international agreements on shark finning and data collection, provide Congress with annual reports describing efforts to carry out the Shark Finning Prohibition Act, and establish research programs.

National Marine Fisheries Service. (2017). 2017 Shark Finning Report to Congress. Retrieved from https://repository.library.noaa.gov/view/noaa/19769

This report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar year 2016 to implement the 2000 Shark Finning Prohibition Act and more recent shark conservation legislation. The 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction.