Shortfin Mako Shark (*Isurus oxyrinchus*)

Bibliography

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NCRL subject guide 2021-09
https://doi.org/10.25923/gr9x-vv55

June 2021

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National Oceanic and Atmospheric Administration
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Background & Scope

NMFS is conducting a status review of the shortfin mako shark (*Isurus oxyrinchus*) in response to a petition to list the species as threatened or endangered under the U.S. Endangered Species Act. The purpose of a status review is to synthesize the best available scientific and commercial information regarding the species' status and evaluate extinction risk of the species to determine if listing is warranted. The information used in a status review includes the life history and ecology of the species, taxonomy, historical and current abundance, trends, population growth rate, distribution, population connectivity, genetic diversity, and threats facing the species. As NMFS has not conducted a review of the species' status in the past, we are compiling the best available data from any year through the present, as opposed to a specific timeframe.

The shortfin mako is a large pelagic shark that occurs across all temperate and tropical ocean waters. This bibliography focuses on shortfin mako literature from peer-reviewed journals, technical reports, memos, and Regional Fisheries Management Council reports. It is intended as a reference resource for ESA staff of the NOAA Fisheries Office of Protected Resources when compiling any relevant information on the status of the species. It is organized into five sections: Biology (life history), Ecology (interaction with the environment), Genetics, Population Abundance and Trends, and Threats.

Section I – Biology

Section one is intended to provide an overview of the life history of the shortfin mako shark. The research in this area includes information on physical attributes and characteristics, historical and current habitat and distribution, diet, lifespan, migration patterns, behavior, feeding, productivity, fecundity, growth and reproduction. If biology and life history varies by region (e.g. Atlantic Ocean vs. Pacific Ocean), this is important to note as well.

Section II – Ecology

Section two is intended to provide an overview of how the shortfin mako interacts with the environment. The research in this area includes information on feeding ecology, food resources, prey composition, competition and predation pressure, and how climate change affects the species.

Section III – Genetics

Section three is intended to review any information regarding the genetic variation among and between populations of shortfin makos, including genetic information that sheds light on population structure and that may inform NMFS's application of the DPS policy for the species.

Section IV – Population Abundance and Trends

Section four is intended to provide an overview of historical and current population estimates and trends for the shortfin mako shark throughout its range. These data are often found in fisheries stock assessment reports. This section should also include any demographic features and trends that influence abundance, including birth and mortality rates, age structure, sex ratio, age at mortality, etc.

Section IV – Threats

A threat is defined as any factor that could represent an impediment to a species' recovery. Section four is intended to provide an overview of any threats to the species, including incidental catch (bycatch) in commercial fisheries; directed/targeted commercial, artisanal and recreational fisheries; opportunistic retention when bycaught; domestic and international trade in shark fins, meat and products; pollution; climate change; disease; habitat degradation; and any other threats that may be documented in the

literature. It should also include management, regulatory, or conservation programs for *I. oxyrinchus*, including mitigation measures related to any known or potential threats to the species throughout its range

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; EBSCO Academic Search Complete and Environment Complete; ProQuest Aquatic Sciences and Fisheries Abstracts; NOAA Institutional Repository; BioDiversity Heritage Library; BioOne Complete; Dimensions; Lens; JSTOR and Google Scholar. The bibliography includes English, Spanish and Chinese language materials.

Section I: Biology

Afroz, F., Lang, A., Habegger, M. L., Motta, P., & Hueter, R. (2016). Experimental Study of Laminar and Turbulent Boundary Layer Separation Control of Shark Skin. *Bioinspiration & Biomimetics, 12*(1), 016009 https://doi.org/10.1088/1748-3190/12/1/016009

The Shortfin Mako shark (*Isurus oxyrinchus*) is a fast swimmer and has incredible turning agility, and has flexible scales known to bristle up to 50 degrees in the flank regions. It is purported that this bristling capability of the scales may result in a unique pass flow control method to control flow separation and reduce drag. It appears that the scales have evolved to be only actuated when the flow over the body is reversed; thereby inducing a method of inhibiting flow reversal close to the surface. In addition, bristled scales form cavities which could induce boundary layer mixing and further assist in delaying flow separation. To substantiate the hypothesis, samples of skin from the flank region of the mako have been tested in a water tunnel facility under various strengths of adverse pressure gradient (APG). Laminar and turbulent separation over the skin was studied experimentally using time-resolved digital particle image velocimetry, where the APG was generated and varied using a rotating cylinder. Shark skin results were compared with that of a smooth plate data for a given amount of APG. Both the instantaneous and time-averaged results reveal that shark skin is capable of controlling laminar as well as turbulent separation. Under laminar conditions, the shark skin also induces an early transition to turbulence and reduces the degree of laminar separation. For turbulent separation, the presence of the shark skin reduces the amount of backflow and size of the separation region. Under both flow conditions, the shark skin also delayed the point of separation as compared to a smooth wall.

Ardizzone, D., Cailliet, G. M., Natanson, L. J., Andrews, A. H., Kerr, L. A., & Brown, T. A. (2006). Application of Bomb Radiocarbon Chronologies to Shortfin Mako (*Isurus oxyrinchus*) Age Validation. *Environmental Biology of Fishes, 77*(3-4), 355-366 https://doi.org/10.1007/s10641-006-9106-4

Age estimation is an issue for the shortfin mako, *Isurus oxyrinchus*, because of disagreement on vertebral band-pair deposition periodicity. In the 1950s-1960s, thermonuclear testing released large amounts of radiocarbon into the atmosphere, which diffused into the ocean through gas exchange. This influx created a time-specific marker that can be used in age validation. Annual band-pair deposition in the porbeagle, *Lamna nasus*, was validated in a previous study and indicated preliminary annual deposition in the shortfin mako, using four samples from one vertebra. In the present study, age estimates from 54 shortfin mako vertebrae collected in 1950-1984 ranged 1-31 years. Ageing error between readers was consistent, with 76% of the estimates ranging within 2 years. Twenty-one Delta C-14 values from eight shortfin mako vertebrae (collected in the western North Atlantic in 1963-1984) ranged -154.8 parts per thousand to 86.8 parts per thousand. The resulting conformity with the Delta C-14 timeline for the porbeagle supported annual band-pair deposition in vertebrae of the shortfin mako.

Barker, M. J., & Schluessel, V. (2005). Managing Global Shark Fisheries: Suggestions for Prioritizing Management Strategies. *Aquatic Conservation-Marine and Freshwater Ecosystems, 15*(4), 325-347 https://doi.org/10.1002/aqc.660

1. Over the past two decades the number of fisheries targeting shark resources has increased dramatically. A combination of factors, including relatively slow growth rate, low fecundity and late age

of maturity, result in low recovery rates from exploitation for most shark species. This, in turn, is reflected in the poor record of sustainability of shark fisheries.
2. One of the greatest challenges is to find a way to deal with the substantial levels of shark bycatch taken in many non-target fisheries. Poor general recording of shark landings and paucity of shark landing data at the species level also undermine the development of effective shark management strategies.
3. This paper reviews the problems that must be faced worldwide if shark resources are to be managed sustainably and lays out a comprehensive set of prioritized management strategies to facilitate the sustainable management of global shark fisheries. It is acknowledged that the majority of sharks are harvested in developing countries and that the management of shark resources in developing and developed countries will need to incorporate different management strategies relevant to local socio-economic agendas. The management recommendations deal with methods to improve the global regulation of fisheries, ways to improve global conservation ethics and encourage active participation in management, as well as means by which specific management strategies may be implemented.

Bengil, E. G. T., Akalın, M., Tüney Kızılkaya, İ., & Bengil, F. (2019). Biology of Shortfin Mako Shark (*Isurus oxyrinchus* Rafinesque, 1810) from the Eastern Mediterranean. *Acta Aquatica Turcica, 15*(4), 424-431 https://doi.org/10.22392/actaquatr.545997

Shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, is one of the commercially and recreationally important shark species in the world. Still knowledge on its biology and status is limited in the eastern Mediterranean. Three individuals were caught from Turkish waters. Two individuals (one female and one male) stomach contents, morphological measurements and female' gonad histology were studied. According to the results from macroscopic examination and gonad histology, the female was a Stage 1-immature, and smallest female ever recorded from Turkish waters. In addition, phylogenetic network of mitochondrial haplotypes was constructed for all three individuals. The phylogenetic network analysis supported that the species having a metapopulation as mentioned in previous studies. Since every information is critical for development of conservation actions aiming endangered species, we believe that our study will contribute to the limited knowledge on *I. oxyrinchus* biology and reproduction habits in Eastern Mediterranean.

Bishop, S. D. H., Francis, M. P., Duffy, C., & Montgomery, J. C. (2006). Age, Growth, Maturity, Longevity and Natural Mortality of the Shortfin Mako Shark (*Isurus oxyrinchus*) in New Zealand Waters. *Marine and Freshwater Research, 57*(2), 143-154 https://doi.org/10.1071/Mf05077

Shortfin mako sharks were aged by counting growth bands in sectioned vertebrae (n=256), and assuming annual band-pair deposition. No systematic ageing bias was present and count precision was high. 0+ juveniles were identified from length-frequency plots and assigned ages based on a theoretical birth date of 1 October and their date of capture. A Schnute generalised growth model fitted to the combined vertebral and 0+ data described the growth patterns best. Shortfin makos grow very rapidly initially, increasing by similar to 39 cm fork length in their first year. Thereafter, males and females grow at similar but slower rates until about age 7 years, after which the relative growth of males declines. Longevity estimates were 29 and 28 years for males and females respectively. Natural mortality (M) is probably in the range of 0.10-0.15. Median ages at maturity were 7-9 years for males and 19-21 years for females. Comparisons of growth curves reported here and elsewhere suggest no regional differences in growth rates. The shortfin mako is a late-maturing species with moderate longevity and low natural

mortality. With these life history characteristics and an unknown stock size and structure worldwide, management should be of a precautionary nature.

Biton-Porsmoguer, S., Banaru, D., Boudouresque, C. F., Dekeyser, I., Bouchoucha, M., Marco-Miralles, F., . . . Harmelin-Vivien, M. (2018). Mercury in Blue Shark (*Prionace glauca*) and Shortfin Mako (*Isurus oxyrinchus*) from North-Eastern Atlantic: Implication for Fishery Management. *Marine Pollution Bulletin, 127*, 131-138 https://doi.org/10.1016/j.marpolbul.2017.12.006

Pelagic sharks (blue shark *Prionace glauca* and shortfin mako *Isurus oxyrinchus*) caught by long-line Spanish and Portuguese fleets in the NE Atlantic, were sampled at Vigo fish market (Spain) for total mercury (Hg) analysis. Hg concentration in white muscle increased with size and weight in both species, but at a higher rate in shortfin mako than in the blue shark. No difference was found with sex, year and season. Spatial variation was observed in the blue shark with higher Hg values in the North of the Azorean archipelago, but not in the shortfin mako. These high-level predators are particularly susceptible to bioaccumulate contaminants (Hg) in their tissues (muscle). However, a significant positive relationship between Hg concentration and trophic level (delta(15)N) of individuals was observed only in the shortfin mako. Most sharks landed were juveniles which presented Hg concentration lower than the maximum limit allowed by the European Union (1mgkg(-1) wet weight) for marketing. However, concentrations above this threshold were most recorded in blue sharks larger than 250cm total length (TL) and in shortfin makos larger than 190cm TL, raising the question of the commercialization of large-sized individuals.

Biton Porsmoguer, S., Dekeyser, I., Banaru, D., Bouchoucha, M., & Marco-Miralles, F. (2016). Using Body Mass Index (BMI) to Estimate Mercury Contamination of the Blue Shark (*Prionace glauca*) and the Shortfin Mako (*Isurus oxyrinchus*). *Cybium, 40*(4), 319-322 Retrieved from https://archimer.ifremer.fr/doc/00373/48439/48700.pdf

Blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) specimens were caught in the North-eastern Atlantic Ocean by Spanish and Portuguese longliners. They are considered as top-predators, particularly susceptible to bioaccumulate mercury (Hg). The Hg mean levels in blue shark and shortfin mako were 0.4 (SD = 0.3 mg kg super(-1)) and 0.5 (SD = 0.9 mg kg super(-1)), respectively. The body mass index (BMI) was tested to demonstrate the accumulation of Hg in these two top-predators, taking into account size (TL, cm) and mass (W, kg) simultaneously. The comparison of these three methods showed that the BMI could be a relevant biological indicator of the accumulative Hg process for sharks.

Borucinska, J. D., & Heger, K. (1999). Disseminated Granulomas Associated with Nematode Larvae in a Shortfin Mako Shark. *J Wildl Dis, 35*(1), 98-100 https://doi.org/10.7589/0090-3558-35.1.98

A shortfin mako shark (*Isurus oxyrinchus*) caught in 1996 by sportfishermen in Long Island (New York, USA) had many granulomas containing larval nematodes. Granulomas were present in the myocardium, spleen, pancreas, stomach, spiral intestine, hematopoietic tissue within the anterior kidney, and in the branchial septum and primary lamellae of the gills. Epicardial hyperplasia and granulomatous myocarditis were associated with the larvae. Although identification of the larvae was impossible due to lack of distinct morphological features, they resembled dracunculoid larvae previously reported from sharks.

Borucinska, J. D., & Tafur, M. (2009). Comparison of Histological Features, and Description of Histopathological Lesions in Thyroid Glands from Three Species of Free-Ranging Sharks from the Northwestern Atlantic, the Blue Shark, *Prionace glauca* (L.), the Shortfin Mako, Isurus Oxyrhinchus Rafinesque, and the Thresher, *Alopias vulpinus* (Bonnaterre). *J Fish Dis, 32*(9), 785-793 https://doi.org/10.1111/j.1365-2761.2009.01056.x

Histomorphological features of piscine thyroids are widely accepted and frequently used as bioindicators of environmental pollution. This despite the fact that there is marked variation in thyroid morphology resulting from numerous pathological and physiological conditions. Our hypothesis was that there will be variations in histological features in thyroids collected from different shark species during the summer season in the northwestern Atlantic. To test our hypothesis, we examined histological features encountered in grossly normal thyroids from three species of sharks, the shortfin mako, Isurus oxyrhinchus, thresher, *Alopias vulpinus* and blue sharks, *Prionace glauca*. In addition, microscopic lesions from these thyroids were described. Ninety-four sharks were collected in summer 2001, 2002 and 2004. Routine, haematoxylin and eosin-stained paraffin-embedded sections were studied by light microscopy. We found inter-species but not intra-species variation in histological patterns of thyroids, which were distinct enough to allow 'blind' assignment of a thyroid to the specific species. The most common lesions encountered were lymphofollicular hyperplasia and chronic thyroiditis. In addition, one case each of intravascular larval nematodes and a myxosporean infection was found. Our results provide the first data on species-specific morphology of thyroids collected during summer months from sharks. The results indicate that familiarity with normal thyroid morphology is crucial before using shark thyroids in biomonitoring of environmental contamination or interpreting data from this gland in shark-health studies.

Borucinska, J. D., Obasa, O. A., Haffey, N. M., Scott, J. P., Williams, L. N., Baker, S. M., . . . Mudimala, R. (2012). Morphological Features of Coronary Arteries and Lesions in Hearts from Five Species of Sharks Collected from the Northwestern Atlantic Ocean. *J Fish Dis, 35*(10), 741-753 https://doi.org/10.1111/j.1365-2761.2012.01405.x

Morphological features of coronary arteries and incidental lesions are reported from hearts in five species of sharks, the shortfin mako shark, Isurus oxyrhinchus Rafinesque, thresher shark *Alopias vulpinus* (Bonaterre), blue shark, *Prionace glauca* L., the smooth dogfish, Mustelus canis (Mitchill), and spiny dogfish, Squalus acanthias L. Sharks were collected from the northwestern Atlantic between June and August from 1996 to 2010. They were necropsied dockside and the hearts were preserved in buffered formalin. Routine sections including ventricle/conus arteriosus and the atrio-ventricular junctions were embedded in paraffin, stained with common histological and immunohistochemical methods and examined by brightfield microscopy. Myointimal hyperplasia, medial myo-myxomatous hyperplasia and bifurcation pads were observed commonly, and medial muscle reorientation and epicardial myeloid tissues were rare. All the above features differed in severity, prevalence and distribution depending on anatomical site and shark species/size. Morphometric analysis indicated that myomyxomatous hyperplasia is associated with luminal narrowing of blood vessels. As suggested previously, the described morphological features are most likely physiological responses to blood flow characteristics. Vascular and cardiac lesions were uncommon and included, granulomatous proliferative epicarditis with fibroepitheliomas, myxomatous epicardial expansions, medial arterial vacuolation, myocardial fibrosis, acute ventricular emboli and parasitic granulomas. The lesions of embolism,

proliferative and granulomatous epicarditis and myocardial fibrosis were in all sharks associated with capture events including retained fishing hooks. The significance and aetiopathogenesis of medial vacuolation and epicardial myxomatous expansions remains unclear.

Cabrera, Y., Aguilar, C., Gonzalez-Sanson, G., & Marquez-Farias, J. F. (2016). Occurrence of an *Isurus oxyrinchus* Pregnant Female to the Northwest of Cuba. *Latin American Journal of Aquatic Research, 44*(1), 184-189 https://doi.org/10.3856/vol44-issue1-fulltext-21

Isurus oxyrinchus is a species mostly caught on pelagic longline fisheries. In this study, the occurrence of *I. oxyrinchus* pregnant female caught to northwest of Cuba is reported; we describe for the first time the development stage of the embryos for this region and compare its development phase with previous surveys carried out in other regions. The adult specimen measured 365 cm TL and had 12 embryos. Regarding the whole litter only a male of 39.3 cm (TL) and a female of 39.2 cm (TL) could be examined. The most evident feature about the embryos was the development of a big abdomen full of small follicles with yolk, corresponding to the oophagic phase. This provides enough energy for their growth and development during the gestation period. This current paper is the first record about second phase or half-term litter of embryonic development for *I. oxyrinchus* in Cuban waters and it complements the information concerning the knowledge of the reproductive biology of this species.

Cailliet, G. M., Martin, L. K., Harvey, J. T., Kusher, D., & Welden, B. (1983). *Preliminary Studies on the Age and Growth of Blue (Prionace glauca), Common Thresher (Alopias vulpinus), and Shortfin Mako (Isurus oxyrinchus) Sharks from California Waters*. Retrieved from https://repository.library.noaa.gov/view/noaa/5591

Two methods of enhancing growth bands on vertebral centra-silver nitrate impregnation and X-radiography have proven to be successful when used on centra from 130 blue, *Prionace glauca*, 143 common thresher, *Alopias vulpinus*, and 44 shortfin mako, *Isurus oxyrinchus*, sharks. Bands were counted and measured, and these data were used to construct growth curves based on the von Bertalanffy and logistic growth models. The problems of verification of these counts, and validation of the periodicity of band formation, have been identified and are discussed in relation to the growth curves generated for each of these three species. Our results and other available Information indicate that these elasmobranchs grow relatively slowly, reaching their asymptotic lengths at 20 yr of age for blue sharks, and between 45 and 50 yr for shortfin mako and common thresher sharks. They have a large size but relatively early age of first reproductive maturity, and low fecundities. This combination of traits could make them susceptible to overfishing.

Caira, J. N., Jensen, K., Pickering, M., Ruhnke, T. R., & Gallagher, K. A. (2020). Intrigue Surrounding the Life-Cycles of Species of Clistobothrium (Cestoda: Phyllobothriidea) Parasitising Large Pelagic Sharks. *Int J Parasitol, 50*(13), 1043-1055 https://doi.org/10.1016/j.ijpara.2020.08.002

This study aimed to locate the adults, and thus also the definitive hosts, of three species of marine mammal-parasitising larval cestodes that have molecular affinities with Clistobothrium. New collections led to the discovery of adults of two new species of Clistobothrium, one from the longfin mako shark and one from the salmon shark. New material of Clistobothrium tumidum was collected from the great white shark and new material of a previously reported undescribed species of Clistobothrium was

collected from the porbeagle shark. Larvae of Clistobothrium were opportunistically collected from sockeye salmon and four species of small squaliform sharks. Sequence data for the D1-D3 region of the 28S rDNA gene were generated for all but one of these taxa. The tree resulting from maximum likelihood analysis of those data, in combination with comparable data from GenBank, indicates that squaliform sharks can serve as intermediate hosts for the species from the porbeagle shark. The larvae from salmon exhibit a unique molecular signature and, based on diet data, may be conspecific with adults from the salmon shark. Informed by sequence data for new material of Monorygma and existing data for Phyllobothrium, the larvae provisionally identified as Monorygma grimaldii and Phyllobothrium delphini were formally transferred to Clistobothrium. Especially puzzling was that the molecular signatures of none of the eight species of Clistobothrium match those of the three marine mammal-parasitising larval forms. We are at a loss as to where else to look for the three corresponding adult forms. The great white shark remains the most likely candidate given it consumes marine mammals with some regularity, but seems unlikely to host five species of Clistobothrium. Alternatively, we are left wondering if the large marine mammal predator Carcharocles megalodon may not be extinct after all.

Campana, S. E., Natanson, L. J., & Myklevoll, S. (2002). Bomb Dating and Age Determination of Large Pelagic Sharks. *Canadian Journal of Fisheries and Aquatic Sciences, 59*(3), 450-455 https://doi.org/10.1139/F02-027

Despite their notoriety and role as apex predators, the longevity of large pelagic sharks such as the porbeagle (*Lamna nasus*) and shortfin mako (*Isurus oxyrinchus*) is unknown. Vertebral growth bands provide an accurate indicator of age in young porbeagle, but age validation has never been reported for any large shark species past the age of sexual maturity. Here, we report the first application of bomb radiocarbon as an age validation method for long-lived sharks based on date-specific incorporation of radiocarbon into vertebral growth bands. Our results indicate that porbeagle vertebrae recorded and preserved a bomb radiocarbon pulse in growth bands formed during the 1960s. Through comparison of radiocarbon assays in young, known-age porbeagle collected in the 1960s with the corresponding growth bands in old porbeagle collected later, we confirm the validity of porbeagle vertebral growth band counts as accurate annual age indicators to an age of at least 26 years. The radiocarbon signatures of porbeagle vertebral growth bands appear to be temporally and metabolically stable and derived mainly from the radiocarbon content of their prey. Preliminary radiocarbon assays of shortfin mako vertebrae suggest that current methods for determining shortfin mako age are incorrect.

Campana, S. E., Marks, L., & Joyce, W. (2004). *Biology, Fishery and Stock Status of Shortfin Mako Sharks (Isurus oxyrinchus) in Atlantic Canadian Waters*. (Research Document 2004/094). Dartmouth, Nova Scotia: Marine Fish Division, Bedford Institute of Oceanography, Retrieved from http://www.dfo-mpo.gc.ca/csas/

Shortfin makos are a high-value bycatch of pelagic longline fisheries off the eastern coast of Canada. Annual catches in Canadian waters average 60-80t per year. Both Canadian and U.S. tagging studies indicate that makos are highly migratory, seasonal residents of Canadian waters, representing the northern extension of a North Atlantic-wide population centred at more southerly latitudes. Therefore, Canadian catches represent but a small part of that estimated for the population as a whole.

The two indices of population abundance examined in this analysis did not provide a consistent view of mako shark population status. A standardized catch rate index from the commercial large pelagic fishery

suggested stable abundance since 1988. However, the analysis did not have the statistical power to detect anything less than a severe decline. In contrast, the median size of mako sharks in the commercial catch has declined since 1998, suggesting a loss of larger sharks.

It is widely recognized that elasmobranchs are unproductive compared with teleosts, largely as a result of their low fecundity and late age at sexual maturation. Published results suggest that makos are somewhat more productive than many other sharks. However, this conclusion was based in part on growth studies which have recently been discredited; the results presented here and elsewhere indicate that makos grow more slowly than was previously reported. Nevertheless, the more rapid growth and greater fecundity of makos compared to porbeagles implies that makos should be somewhat more resilient to exploitation than are porbeagles (which are severely overexploited in Canadian waters).

In summary, shortfin makos in Atlantic Canadian waters represent the margins of the distribution of the population, and are fished most heavily outside of the Canadian EEZ. Given the bycatch nature of the fishery in Canada, it appears unlikely that current exploitation rates in Canada are having an appreciable impact on the population. Nevertheless, there are some signs that the population is declining in abundance, implying that continued monitoring is warranted.

Carey, F. G., Middleton, L., Stillwell, C., Pratt, H., Kohler, N., & Cavin, C. (1978). Mako Shark Experiment on Wieczno, March 1978. *National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole Laboratory, Document*(80-7), 12 Retrieved from https://apps-nefsc.fisheries.noaa.gov/rcb/publications/series/whlrd/whlrd7827.pdf

Mako, Isurus oxyrinchus, porbeagle, Lamna nassus (and probably the white shark, Carcarodon carcharias) have warm bodies. As is the case with other warm fish, these lamnid sharks conserve their metabolic heat by a system of counter current heat exchangers in their circulatory systems. The viscera, as well as the muscle, are warm. The visceral heat exchanger described by Burne (1923) is located in the hepatic sinuses and consists of an arterial tree which divides and redivides into fine arteries which fill the lumen of the sinus with an arterial sponge (Figure 1). Venous blood from the liver trickles over this sponge in a countercurrent fashion to the arterial flow and heat is transferred from the venous to the arterial blood.

A large venous channel passes through the center of this arterial mass. When this channel is open, venous blood flows through it and not over the arteries. A well-developed sphincter in this channel allows it to be shut off. Clearly, the circulation is arranged so that venous blood can flow through the heat exchanger or be shunted around it. When venous blood flows over the finely divided arteries, metabolic heat passes from the venous to the arterial blood and back into the viscera, causing the temperature to rise. When the shunt is open, the warm venous blood by-passes the heat exchanger, heat is lost and the temperature of the viscera should decrease. Almost certainly this heat exchanger and shunt provide a mechanism for controlling visceral temperature. This heat exchanger and shunt in the Lamnid sharks is the only situation in any of the warm fishes where we have found an anatomical basis for temperature control.

Thus it is an ideal situation for a physiological experiment. We have tried three times in the past to get evidence for temperature control in the stomachs of mako sharks. The experiments involve hauling a shark aboard, placing an acoustic telemetry transmitter in its stomach, then releasing the fish and following it. We hoped to observe temperature variations in the stomach which could be interpreted as resulting from the proposed control system, but in the past the experiments have been inconclusive.

Cerna, F., & Licandeo, R. (2009). Age and Growth of the Shortfin Mako (*Isurus oxyrinchus*) in the South-Eastern Pacific Off Chile. *Marine and Freshwater Research, 60*(5), 394-403 https://doi.org/10.1071/Mf08125

The shortfin mako, *Isurus oxyrinchus*, is a large pelagic shark with a widespread global distribution. However, very little is known about most aspects of this species for the south-eastern Pacific. In the present paper, the age and growth parameters of the shortfin mako, caught by Chilean swordfish longline fisheries from 2004 to 2005, are reported. Ages were estimated by counting band-pairs from sections of vertebral centra from 547 individuals, ranging from 76 to 330 cm in total length (TL). Trends in the proportion of opaque edges for all ages combined and grouped into ages 0-6 and 7-26 years indicated that they are formed during summer and showed that annually, one band-pair is formed in the vertebrae of shortfin makos. Modal-progression analysis was used to verify the first three age classes (ages 0-2 years). For both sexes, the oldest estimated age was 25+ years. Von Bertalanffy growth parameters were estimated at L(infinity) = 325.29 cm TL, K=0.076 year(-1) and t(0)=-3.18 years for females and L(infinity)=296.60 cm TL, K=0.087 year(-1) and t(0)=-3.58 years for males. The results indicated that this species is highly vulnerable to exploitation and, thus, urgent conservation measures are required.

Conde-Moreno, M., & Galvan-Magana, F. (2006). Reproductive Biology of the Mako Shark *Isurus oxyrinchus* on the South-Western Coast of Baja California, Mexico. *Cybium, 30*(4), 75-83 Retrieved from https://sfi-cybium.fr/sites/default/files/pdfs-cybium/08.CondeMoreno.pdf

The mako shark is an important target for commercial and sport fishing on the south-western coast of Baja California, but few biological studies have been carried out on this species in Mexico. A sample of 301 individuals (153 females and 148 males) was collected from the landings of traditional fisheries. The size of the specimens ranged from 69 cm to 290 cm TL. The sex ratio was 1.03/1. The males were found in three stages of maturity: immature, sub-adult and mature, while the females in only the first two stages. Male mako sharks mature at about 180 cm TL. They showed radial type spermatocyst development, of which seven stages were differentiated. Females showed an internal type ovary, and only three differentiated stages of ovarian follicle development. As many sharks caught were juveniles or neonates, it is suggested that the south-western coast of Baja California represents a nursery area for the mako shark.

Costa, F. E., Braga, F. M., Arfelli, C. A., & Amorim, A. F. (2002). Aspects of the Reproductive Biology of the Shortfin Mako, *Isurus oxyrinchus* (Elasmobranchii Lamnidae), in the Southeastern Region of Brazil. *Braz J Biol, 62*(2), 239-248 https://doi.org/10.1590/s1519-69842002000200007

Uteri from four pregnant females and two newborn of shortfin mako, *Isurus oxyrinchus*, were collected in the southeastern region of Brazil, during September, October, and November of 1993 and 1994. All embryos were near-term with developing dentition and inner organs. Total length ranged from 64.5 to 72.0 cm, and the maximum number of embryos observed in a litter was 20. These observations further confirmed oophagy as a form of nutrition in this species, and its periodicity. The presence of teeth in the embryos' stomachs suggest that tooth replacement begins in the uterine phase.

Dickson, K. A., Dall, A. V., Eisman, J. M., McDonnell, E. T., & Hendrzak, A. M. (1989). Biochemical Indices of Aerobic and Anaerobic Capacity in Red and White Myotomal Muscle of Active, Pelagic Sharks: Comparisons between Endothermic and Ectothermic Species. *Journal of the Pennsylvania Academy of Science, 62*(3), 147-151 Retrieved from http://www.jstor.org/stable/44148841

To assess the aerobic and anaerobic metabolic capacities of the red and white myotomal muscle of active, pelagic sharks, the activities of the enzymes citrate synthase (CS), β-hydroxy-O-acylCoA dehydrogenase (HOAD), pyruvate kinase (PK), lactate dehydrogenase (LDH), and creatine phosphokinase (CPK) were measured in *Isurus oxyrinchus* (shortfin mako), *Sphyrna lewini* (scalloped hammerhead), *Prionace glauca* (blue), Carcharhinus plumbeus (sandbar), and Carcharhinus limbatus (blacktip). The mako shark, an endothermic species capable of maintaining myotomal muscle temperature elevated above ambient water temperature, was compared with the four ectothermic species. In white but not red muscle, CS activity, an index of tissue aerobic capacity, was greater in mako than in the other four species. Compared with the ectotherms, red muscle of the mako shark had a lower HOAD activity, an index of the capacity for β-oxidation of fatty acids. White muscle HOAD did not differ significantly between endotherms and ectotherms. In both red and white muscle, the activities of PK and LDH, indices of a tissue's potential for glycolysis, and of CPK were greater in the mako shark than in the ectothermic species. Thus, indices of aerobic capacity in red muscle did not differ between endothermic and ectothermic shark species, but, in white muscle, both aerobic and anaerobic potentials were greater in mako than in the four ectothermic species. Similar results have been found in comparisons of endothermic and ectothermic teleost fishes of the Family Scombridae. However, the sharks had much lower muscle enzymic activities than do teleosts, corresponding with their lower swimming speeds. Due to the elevated and relatively stable temperature of the red muscle in endothermic fishes, red muscle contraction rate and power output for sustainable, cruise swimming may be greater than in ectotherms, precluding the necessity of increasing enzyme levels to achieve higher rates of ATP production. On the other hand, to increase burst swimming capabilities, endothermic species may have to elevate the activities of enzymes of both aerobic and anaerobic ATP generating pathways in white muscle.

Diez, G., Soto, M., & Blanco, J. M. (2015). Biological Characterization of the Skin of Shortfin Mako Shark *Isurus oxyrinchus* and Preliminary Study of the Hydrodynamic Behaviour through Computational Fluid Dynamics. *Journal of Fish Biology, 87*(1), 123-137 https://doi.org/10.1111/jfb.12705

This study characterized the morphology, density and orientation of the dermal denticles along the body of a shortfin mako shark *Isurus oxyrinchus* and identified the hydrodynamic parameters of its body through a computational fluid-dynamics model. The study showed a great variability in the morphology, size, shape, orientation and density of dermal denticles along the body of *I. oxyrinchus*. There was a significant higher density in dorsal and ventral areas of the body and their highest angular deviations were found in the lower part of the mouth and in the areas between the pre-caudal pit and the second dorsal and pelvic fins. A detailed three-dimensional geometry from a scanned body of a shark was carried out to evaluate the hydrodynamic properties such as drag coefficient, lift coefficient and superficial (skin) friction coefficient of the skin together with flow velocity field, according to different roughness coefficients simulating the effect of the dermal denticles. This preliminary approach contributed to detailed information of the denticle interactions. As the height of the denticles was increased, flow velocity and the effect of lift decreased whereas drag increased. The highest peaks of skin friction coefficient were observed around the pectoral fins.

Domingues, R., Mastrochirico-Filho, V. A., Mendes, N., Hashimoto, D., Coelho, R., Cruz, V., . . . Mendonca, F. (2019). De Novo Transcriptome Assembly, Annotation and Snp Discovery of the Shortfin Mako (*Isurus oxyrinchus*). *Frontiers in Marine Science, 6* https://doi.org/10.3389/conf.fmars.2019.07.00050

The shortfin mako, *Isurus oxyrinchus* is an oceanic pelagic shark species found worldwide in tropical and subtropical waters. It is one of the most frequently shark caught by pelagic longline fisheries, and despite its commercial importance and ecological significance, the understanding of its biology at molecular level is still incipient. Therefore, we used a deep RNA sequencing analysis of the eye and liver tissue from four shortfin mako individuals to characterize the genes of both organs. A total of 89,95 Gb raw reads were obtained by Illumina paired-end sequencing technology (Hiseq 4000). De novo transcriptome from eye and liver yielded a total of 506,686,525 reads and 336,210 contigs. A total of 274,218 and 310, 628 contigs were mapped for eye and liver, respectively, and 37,227 (11.04%) sequences were successfully annotated based on sequence similarities against the Uni-Prot, the Kyoto Encyclopedia of Genes and Genomes (KEGG), and the NCBI non-redundat (NR) protein database. Of these, 31,479 (84.55%) sequences exhibited gene ontology term, which 86.068 (47.8%) were associated with biological process, 55,194 (30.6%) with molecular function, and 39,175 (21.6%) with cellular component. The most frequent terms were: cellular process, single-organism process, and metabolic process for biological process, binding, catalytic activity, and transporter activity for molecular function, and cell, organelle, and membrane for cellular component. In addition, 1,801 genes were found associated to the imune system, 1,090 to growth, 520 to behaviour, and 344 to reproduction. A total of 129,663 putative single nucleotide polymorphism (SNPs) were found in shortfin mako shark. Among them, 78, 598 were putative annotated SNPs, with 14,842 (19%) in coding regions and 63,756 (81%) in non-coding regions. After filtering procedure 1,166 SNPs were selected. Our results provide valuable sequence resources for future functional and populational studies of the globally vulnerable shortfin mako shark.

Donley, J. M., Shadwick, R. E., Syme, D., & Sepulveda, C. A. (2004). Contractile Properties of Aerobic Locomotor Muscle in the Leopard Shark and Shortfin Mako Shark. *Integrative and Comparative Biology, 44*(6), 691-691 Retrieved from https://sicb.burkclients.com/meetings/2005/schedule/abstractdetails.php3?id=504

The work loop technique was used to examine the contractile properties of the red aerobic locomotor muscle (RM) in the leopard shark (Triakis semifasciata) and shortfin mako shark (*Isurus oxyrinchus*). The effects of axial position and temperature on the stimulus duration and phase producing maximum net positive work and power output were investigated. Contractile performance was measured at multiple temperatures from 10 to 26C at cycle frequencies (analogous to tailbeat frequencies) ranging from 0.25 to 3 Hz using muscle bundles isolated from anterior (A) (0.4L where L is total body length) and posterior (P)(0.6-0.65L) axial positions. There was no significant difference in optimal stimulus duration, phase, net work, power output or isometric twitch kinetics in A and P bundles. Stimulus duration yielding maximum power decreased and optimal phase occurred earlier with increasing cycle frequency. Values for duration and phase, as well as the time course for isometric twitches were statistically similar between the two species. Temperature had little effect on optimal cycle frequencies for power output in the leopard shark, but frequencies increased dramatically (0.25 to 2 Hz) from 10 to 26C in the mako. The data presented here support the hypothesis that the contractile properties of RM are constant along the

body in both species. In addition, these data identify a significant difference in the effect of temperature on net work and power output in these two shark species, such that at temperatures which reflect those normally experienced in the mako the optimal cycle frequency is nearly double that of the leopard shark, suggesting that the mako may be able to maintain greater overall aerobic swimming speeds.

Donley, J. M., Shadwick, R. E., Sepulveda, C. A., & Syme, D. A. (2007). Thermal Dependence of Contractile Properties of the Aerobic Locomotor Muscle in the Leopard Shark and Shortfin Mako Shark. *Journal of Experimental Biology, 210*(Pt 7), 1194-1203 https://doi.org/10.1242/jeb.02730

The work loop technique was used to examine contractile properties of the red aerobic locomotor muscle (RM) in the ectothermic leopard shark Triakis semifasciata and endothermic shortfin mako shark *Isurus oxyrinchus*. The effects of axial position and temperature on the twitch kinetics, and the stimulus duration and phase producing maximum net positive work and power output were investigated. Contractile performance was measured over the temperature range of 15 to 25 degrees C for Triakis and 15 to 28 degrees C for Isurus at cycle frequencies (analogous to tailbeat frequencies) ranging from 0.25 to 3 Hz using muscle bundles isolated from anterior (0.4 L where L is total body length) and posterior (0.6-0.65 L) axial positions. Pairwise comparisons of twitch times for anterior and posterior muscle samples indicated that there were no significant differences related to body position, except in mako sharks at unphysiologically cool temperatures (<20 degrees C). We found no significant differences in optimal stimulus duration, phase, net work or power output between anterior and posterior bundles in each species. With increasing cycle frequency the stimulus duration yielding maximum power decreased while optimal phase occurred earlier. The cycle frequency at which peak power was generated in leopard shark RM was only affected slightly by temperature, increasing from about 0.6 to 1.0 Hz between 15 and 25 degrees C. In contrast, mako RM showed a much more dramatic temperature sensitivity, with the peak power frequency rising from <0.25 to 2.25 Hz between 15 and 28 degrees C. These data support the hypothesis that the contractile properties of RM are functionally similar along the body in both species. In addition, our data identify a significant difference in the effect of temperature on net work and power output between these two shark species; at 15 degrees C muscle from the ectothermic leopard shark performs relatively well in comparison with mako, while at higher temperatures, which reflect those normally experienced by the mako, the optimal cycle frequency for power is nearly double that of the leopard shark, suggesting that the mako may be able to maintain greater aerobic swimming speeds.

Donley, J. M., Shadwick, R. E., Sepulveda, C. A., Konstantinidis, P., & Gemballa, S. (2005). Patterns of Red Muscle Strain/Activation and Body Kinematics During Steady Swimming in a Lamnid Shark, the Shortfin Mako (*Isurus oxyrinchus*). *Journal of Experimental Biology, 208*(Pt 12), 2377-2387 https://doi.org/10.1242/jeb.01618

The dynamics of steady swimming were examined in the shortfin mako (*Isurus oxyrinchus*), a member of the cartilaginous fish family Lamnidae, a family known for their morphological adaptations for high-performance locomotion and their similarity in hydromechanical design to tunas. Patterns of red muscle (RM) strain (i.e. relative length change) and activation were quantified at two axial positions (approximately 0.4 and 0.6L, where L is total body length), using sonomicrometry and electromyography (EMG), and correlated with simultaneous measurements of dorsal midline kinematics during steady swimming (approximately 0.5-1 L s(-1)). RM strain varied longitudinally with strain amplitudes ranging from 5.5+/-1.1% (s.e.m.) in the anterior to 8.7+/-0.9% in the posterior. We found no significant

longitudinal variation in patterns of RM activation, with mean onset of activation occurring at 83-84 degrees (90 degrees is peak length) and offset at 200-210 degrees at both body positions. Likewise, duty cycles were similar: 35.5+/-1.0% in the anterior and 32.2+/-1.6% in the posterior. Comparison of the timing of waves of dorsal midline curvature and predicted strain relative to measured RM strain revealed a phase shift between RM shortening and local body bending. Furthermore, when the body is bent passively, RM shortens synchronously with the surrounding white muscle (WM) and skin, as expected. During active swimming, peaks in RM strain were delayed relative to peaks in WM strain by a mean of approximately 10% of the tailbeat cycle, with one individual as high as approximately 17% in the anterior and nearly 50% in the posterior. The longitudinal consistency in the EMG/strain phase relationship in the mako is similar to that in the leopard shark, suggesting a consistent trend among sharks using different locomotor modes. However, unlike in the leopard shark, RM shortening in the mako is physically uncoupled from deformation of the surrounding body during steady swimming, a characteristic shared between the mako and tunas.

Dono, F., Montealegre-Quijano, S., Domingo, A., & Kinas, P. G. (2015). Bayesian Age and Growth Analysis of the Shortfin Mako Shark *Isurus oxyrinchus* in the Western South Atlantic Ocean Using a Flexible Model. *Environmental Biology of Fishes, 98*(2), 517-533 https://doi.org/10.1007/s10641-014-0284-1

Age and growth estimates of shortfin mako sharks *Isurus oxyrinchus* from the western South Atlantic Ocean were obtained through the analysis of vertebral sections of 245 specimens (126 females, 116 males and 3 with undetermined sex), ranging in size from 78 to 330 cm fork length (FL), using a flexible growth model (Schnute model) and a Bayesian approach. A significant linear relationship was found between FL and vertebral radius for sexes combined. Marginal increment analyses were inconclusive about periodicity of growth band deposition and an annual periodicity was assumed to make age estimations. Specimens were estimated to be between 0 and 28 years of age. The Schnute model provided a good description of the individual growth for both sexes up to 15 years of age. Shortfin mako growth during the first year of life was 33.9 cm (ICr95% = 19.9-40.8) for females and 30.5 cm (ICr95% = 25.6-35.4) for males. Until approximately 15 years of age, both sexes showed similar growth and reached similar to 217 cm FL. Sigmoid shaped growth curves obtained for both sexes indicated a change in the growth pattern close to 7 years of age. Inconclusive results about periodicity of growth band deposition in the study area make necessary the application of more robust validation techniques in the future. Meanwhile, a precautionary approach that assumes an annual deposition pattern in the western South Atlantic can be used for the assessment and management of stocks of this species, characterized by low fecundity and late maturity.

Du Clos, K. T., Lang, A., Devey, S., Motta, P. J., Habegger, M. L., & Gemmell, B. J. (2018). Passive Bristling of Mako Shark Scales in Reversing Flows. *J R Soc Interface, 15*(147) https://doi.org/10.1098/rsif.2018.0473

Shark skin has been shown to reduce drag in turbulent boundary layer flows, but the flow control mechanisms by which it does so are not well understood. Drag reduction has generally been attributed to static effects of scale surface morphology, but possible drag reduction effects of passive or active scale actuation, or 'bristling', have been recognized more recently. Here, we provide the first direct documentation of passive scale bristling due to reversing, turbulent boundary layer flows. We recorded and analysed high-speed videos of flow over the skin of a shortfin mako shark, *Isurus oxyrinchus* These

videos revealed rapid scale bristling events with mean durations of approximately 2 ms. Passive bristling occurred under flow conditions representative of cruise swimming speeds and was associated with two flow features. The first was a downward backflow that pushed a scale-up from below. The second was a vortex just upstream of the scale that created a negative pressure region, which pulled up a scale without requiring backflow. Both flow conditions initiated bristling at lower velocities than those required for a straight backflow. These results provide further support for the role of shark scale bristling in drag reduction.

Duffy, C., & Francis, M. P. (2001). Evidence of Summer Parturition in Shortfin Mako (*Isurus oxyrinchus*) Sharks from New Zealand Waters. *New Zealand Journal of Marine and Freshwater Research, 35*(2), 319-324 https://doi.org/10.1080/00288330.2001.9517001

A litter of eight near-term shortfin mako (*Isurus oxyrinchus* Rafinesque 1810) embryos is described from a 317.5 cm total length (TL) female caught off Hawke Bay, south-east North Island, New Zealand on 5 February 1999. The embryos (3 males and 5 females) were 67.2-77.0 cm TL. Embryo length, condition, hepato-somatic indices. and mass of yolk in their stomachs all indicate they were close to birth. This is the first shortfin make litter reported from New Zealand and is outside the late winter-early spring parturition period predicted from estimated embryonic and juvenile growth rates. Uterine width data from four mature non-pregnant females and age-0+length-at-capture data suggest parturition occurs from September to late February (late winter-mid summer) but is infrequent after January. We suggest that shortfin makos have an extended parturition period, possibly year-round, with peak parturition occurring in late winter-spring.

Duong, C. A., Sepulveda, C. A., Graham, J. B., & Dickson, K. A. (2006). Mitochondrial Proton Leak Rates in the Slow, Oxidative Myotomal Muscle and Liver of the Endothermic Shortfin Mako Shark (*Isurus oxyrinchus*) and the Ectothermic Blue Shark (*Prionace glauca*) and Leopard Shark (Triakis Semifasciata). *J Exp Biol, 209*(Pt 14), 2678-2685 https://doi.org/10.1242/jeb.02317

Mitochondrial proton leak was assessed as a potential heat source in the slow, oxidative (red) locomotor muscle and liver of the shortfin mako shark (*Isurus oxyrinchus*), a regional endotherm that maintains the temperature of both tissues elevated above ambient seawater temperature. We hypothesized that basal proton leak rates in red muscle and liver mitochondria of the endothermic shortfin mako shark would be greater than those of the ectothermic blue shark (*Prionace glauca*) and leopard shark (Triakis semifasciata). Respiration rate and membrane potential in isolated mitochondria were measured simultaneously at 20 degrees C using a Clark-type oxygen electrode and a lipophilic probe (triphenylmethylphosphonium, TPMP(+)). Succinate-stimulated respiration was titrated with inhibitors of the electron transport chain, and the non-linear relationship between respiration rate and membrane potential was quantified. Mitochondrial densities of both tissues were measured by applying the point-contact method to electron micrographs so that proton leak activity of the entire tissue could be assessed. In all three shark species, proton leak occurred at a higher rate in red muscle mitochondria than in liver mitochondria. For each tissue, the proton leak curves of the three species overlapped and, at a membrane potential of 160 mV, mitochondrial proton leak rate (nmol H(+) min(-1) mg(-1) protein) did not differ significantly between the endothermic and ectothermic sharks. This finding indicates that red muscle and liver mitochondria of the shortfin mako shark are not specialized for thermogenesis by having a higher proton conductance. However, mako mitochondria did have higher succinate-stimulated respiration rates and membrane potentials than those of the two ectothermic sharks. This means that

under in vivo conditions mitochondrial proton leak rates may be higher in the mako than in the ectothermic species, due to greater electron transport activity and a larger proton gradient driving proton leak. We also estimated each tissue's total proton leak by combining mitochondrial proton leak rates at 160 mV and tissue mitochondrial density data with published values of relative liver or red muscle mass for each of the three species. In red muscle, total proton leak was not elevated in the mako shark relative to the two ectothermic species. In the liver, total proton leak would be higher in the mako shark than in both ectothermic species, due to a lower proton conductance in the blue shark and a lower liver mitochondrial content in the leopard shark, and thus may contribute to endothermy.

Emery, S. H. (1986). Hematological Comparisons of Endothermic Vs Ectothermic Elasmobranch Fishes. *Copeia, 1986*(3), 700-705 https://doi.org/10.2307/1444952

Hemoglobin and hematocrit levels in the endothermic great white shark, Atlantic shortfin mako and common thresher shark are significantly greater than the values found in ectothermic blue sharks, sandbar sharks, dusky sharks, tiger sharks and scalloped hammerhead sharks. Hemoglobin and hematocrit levels in the former three species equal or exceed reported values for a large number of birds and mammals. Unlike hemoglobin or hematocrit levels, mean corpuscle hemoglobin concentrations, mean erythrocyte size and relative percentages of erythrocyte types in the circulating blood exhibit no correlations with the endothermic vs ectothermic condition in those elasmobranch species examined. Results indicate that the great white, Atlantic shortfin mako and common thresher possess the hematological capabilities to supply oxygen to the body tissues in amounts sufficient to maintain a high energy, endothermic physiology.

Emery, S. H., Mangano, C., & Randazzo, V. (1985). Ventricle Morphology in Pelagic Elasmobranch Fishes. *Comp Biochem Physiol A Comp Physiol, 82*(3), 635-643 https://doi.org/10.1016/0300-9629(85)90445-1

Ventricle weights of the warm-bodied great white shark, Atlantic shortfin mako, and the common thresher shark (the latter presumed to be warm-bodied) are similar to those of ectothermic blue sharks, sandbar sharks, dusky sharks, tiger sharks and scalloped hammerhead sharks. Ventricle muscularity, as estimated by the ratio of cortical to spongy layer thickness, is almost twice as great in the former three species than in the latter elasmobranchs. Measurements of ventricular volumes suggest that the ventricles of the great white, Atlantic shortfin mako and common thresher sharks are better adapted to respond to demands for increases in cardiac output via increased heartbeat frequency in comparison with ectothermic species of shark.

Enax, J., Janus, A. M., Raabe, D., Epple, M., & Fabritius, H. O. (2014). Ultrastructural Organization and Micromechanical Properties of Shark Tooth Enameloid. *Acta Biomater, 10*(9), 3959-3968 https://doi.org/10.1016/j.actbio.2014.04.028

The outer part of shark teeth is formed by the hard and mineral-rich enameloid that has excellent mechanical properties, which makes it a very interesting model system for the development of new bio-inspired dental materials. We characterized the microstructure, chemical composition and resulting local mechanical properties of the enameloid from teeth of *Isurus oxyrinchus* (shortfin mako shark) by performing an in-depth analysis using various high-resolution analytical techniques, including scanning

electron microscopy, qualitative energy-dispersive X-ray spectroscopy and nanoindentation. Shark tooth enameloid reveals an intricate hierarchical arrangement of thin (50-80nm) and long (>1mum) crystallites of fluoroapatite with a high degree of structural anisotropy, which leads to exceptional mechanical properties. Both stiffness and hardness are surprisingly homogeneous in the shiny layer as well as in the enameloid: although both tooth phases differ in structure and composition, they show almost no orientation dependence with respect to the loading direction of the enameloid crystallites. The results were used to determine the structural hierarchy of shark teeth, which can be used as a base for establishing design criteria for synthetic bio-inspired and biomimetic dental composites.

Farrell, A. P., & Davie, P. S. (1991). Coronary Artery Reactivity in the Mako Shark, *Isurus oxyrinchus*. *Canadian Journal of Zoology, 69*(2), 375-379 https://doi.org/10.1139/z91-058

Vasoactivity was examined in isolated vascular rings from the coronary arteries of the mako shark, *Isurus oxyrinchus*, a representative of the athletic elite among elasmobranch fishes. Adenosine relaxed vascular rings. ADP contracted vascular rings at concentrations less than 0.1 mM and relaxed them at higher concentrations. Theophylline inhibited both the ADP-mediated contraction and adenosine-mediated relaxation. Prostaglandin F2α produced strong constrictions. Serotonin had no vasoactive effect. Adrenaline and noradrenaline produced relaxations, indicating a population of β-adrenoceptors. ACh produced weak relaxations at concentrations greater than 10 μM. With the notable exception of the response to adenosine, these vasoactive responses were similar to those previously observed for the coronary arteries in another elasmobranch, the rough skate (Raja nasuta).

Fernandez-Carvalho, J., Coelho, R., Erzini, K., & Santos, M. N. (2015). Modeling Age and Growth of the Bigeye Thresher (*Alopias superciliosus*) in the Atlantic Ocean. *Fishery Bulletin, 113*(4), 468-481 https://doi.org/10.7755/Fb.113.9

The bigeye thresher (*Alopias superciliosus*) is a pelagic shark captured as bycatch in pelagic long-line fisheries. Important information on its biology is still missing, especially from the Atlantic Ocean. In all, 546 vertebrae collected by fishery observers between 2007 and 2009 were used to estimate age and growth parameters for this species in the Atlantic Ocean. The size composition was 102-265 cm fork length (FL) for females and 94-260 cm FL for males. The estimated ages ranged from 0 to 25 years for both sexes. From the 5 growth models used, the 3-parameter von Bertalanffy growth model, reparameterized to estimate length at birth (L-0), produced the best results. The estimated parameters were asymptotic maximum length (L-inf)=284 cm FL, growth coefficient (k)=0.06/year, and L-0=109 cm FL for females and L-inf=246 cm FL, k=0.09/year, and L-0=108 cm FL for males. Although differences between hemispheres indicate slower growth rates in the South Atlantic Ocean, these differences may also have been caused by the lower sample size and larger specimen sizes for the Southern Hemisphere. The estimated growth coefficients are among the lowest found for the Alopiidae, highlighting the bigeye thresher's slow growth and consequent low resilience to fishing pressure.

Francis, M. P., Shivji, M. S., Duffy, C. A. J., Rogers, P. J., Byrne, M. E., Wetherbee, B. M., . . . Meyers, M. M. (2018). Oceanic Nomad or Coastal Resident? Behavioural Switching in the Shortfin Mako Shark (*Isurus oxyrinchus*). *Marine Biology, 166*(1), 1-16 https://doi.org/10.1007/s00227-018-3453-5

Pelagic sharks are vulnerable to overfishing because of their low reproductive rates, generally low growth rates, and high catch rates in tuna and billfish fisheries worldwide. Pelagic sharks often migrate long distances, but they may also occur close to shore, making it difficult to classify their behaviour on the continuum from oceanic nomad to coastal resident. This has important implications for fishery management, which must be targeted at an appropriate spatial scale. Conventional tagging indicates that shortfin mako sharks move widely around the southwest Pacific Ocean, but there is little information on their habitat use or mobility in the region. This study deployed electronic tags on 14 mostly juvenile New Zealand mako sharks to investigate their habitat use, and the spatial and temporal scale of their movements. Movement behaviour was classified as Resident or Travel, with the former focused in New Zealand coastal waters, and the latter in oceanic waters around New Zealand and along oceanic ridges running north towards the tropical islands of Fiji, Vanuatu and New Caledonia. Sharks regularly switched between Resident and Travel behavioural states, but their residency periods sometimes lasted for several months. Sharks spent most of their time in the New Zealand Exclusive Economic Zone (median 77%, five sharks > 90%), presumably because of the high coastal productivity and access to abundant prey. These results challenge the conventional view that mako sharks are nomadic wanderers, and suggest that fishing mortality should be managed at a local as well as a regional scale.

Gemballa, S., Konstantinidis, P., Donley, J. M., Sepulveda, C., & Shadwick, R. E. (2006). Evolution of High-Performance Swimming in Sharks: Transformations of the Musculotendinous System from Subcarangiform to Thunniform Swimmers. *J Morphol, 267*(4), 477-493 https://doi.org/10.1002/jmor.10412

In contrast to all other sharks, lamnid sharks perform a specialized fast and continuous "thunniform" type of locomotion, more similar to that of tunas than to any other known shark or bony fish. Within sharks, it has evolved from a subcarangiform mode. Experimental data show that the two swimming modes in sharks differ remarkably in kinematic patterns as well as in muscle activation patterns, but the morphology of the underlying musculotendinous system (red muscles and myosepta) that drives continuous locomotion remains largely unknown. The goal of this study was to identify differences in the musculotendinous system of the two swimming types and to evaluate these differences in an evolutionary context. Three subcarangiform sharks (the velvet belly lantern shark, Etmopterus spinax, the smallspotted catshark, Scyliorhinus canicula, and the blackmouth catshark, Galeus melanostomus) from the two major clades (two galeans, one squalean) and one lamnid shark, the shortfin mako, Isurus oxyrhinchus, were compared with respect to 1) the 3D shape of myomeres and myosepta of different body positions; 2) the tendinous architecture (collagenous fiber pathways) of myosepta from different body positions; and 3) the association of red muscles with myoseptal tendons. Results show that the three subcarangiform sharks are morphologically similar but differ remarkably from the lamnid condition. Moreover, the "subcarangiform" morphology is similar to the condition known from teleostomes. Thus, major features of the "subcarangiform" condition in sharks have evolved early in gnathostome history: Myosepta have one main anterior-pointing cone and two posterior-pointing cones that project into the musculature. Within a single myoseptum cones are connected by longitudinally oriented tendons (the hypaxial and epaxial lateral and myorhabdoid tendons). Mediolaterally oriented tendons (epineural and epipleural tendons; mediolateral fibers) connect vertebral axis and skin. An individual lateral tendon spans only a short distance along the body (a fraction between 0.05 and 0.075 of total length, L, of the shark). This span is similar in all tendons along the body. Red muscles insert into the midregion of the lateral tendons. The shortfin mako differs substantially from this condition in several respects: Red muscles are internalized and separated from white muscles by a sheath of

lubricative connective tissue. They insert into the anterior part of the hypaxial lateral tendon. Rostrocaudally, this tendon becomes very distinct and its span increases threefold (0.06L anteriorly to 0.19L posteriorly). Mediolateral fibers do not form distinct epineural/epipleural tendons in the mako. Since our morphological findings are in good accordance with experimental data it seems likely that the thunniform swimming mode has evolved along with the described morphological specializations.

Goldman, K. J., & Musick, J. A. (2006). Growth and Maturity of Salmon Sharks (*Lamna ditropis*) in the Eastern and Western North Pacific, and Comments on Back-Calculation Methods. *Fishery Bulletin, 104*(2), 278-292 Retrieved from https://spo.nmfs.noaa.gov/content/growth-and-maturity-salmon-sharks-lamna-ditropis-eastern-and-western-north-pacific-and

Age and growth estimates for salmon sharks (*Lamna ditropis*) in the eastern North Pacific were derived from 182 vertebral centra collected from sharks ranging in length from 62.2 to 213.4 cm precaudal length (PCL) and compared to previously published age and growth data for salmon sharks in the western North Pacific. Eastern North Pacific female and male salmon sharks were aged up to 20 and 17 years, respectively. Relative marginal increment (RMI) analysis showed that postnatal rings form annually between January and March. Von Bertalanffy growth parameters derived from vertebral length-at-age data are L-proportional to=207.4 cm PCL, k=0.17/yr, and t(0)=-2.3 years for females (n=166), and L-proportional to=182.8 cm PCL, k=0.23/yr, and t(0)=-1.9 years for males (n=16). Age at maturity was estimated to range from six to nine years for females (median precaudal length of 164.7 cm PCL) and from three to five years old for males (median precaudal length of 124.0 cm PCL). Weight-length relationships for females and males in the eastern North Pacific are W= 8.2 x 10-(05) x L-2.759 (r(2)=0.99) and W=3.2x 10(-06) x L-3.383 (r2=0.99), respectively. Our results show that female and male salmon sharks in the eastern North Pacific possess a faster growth rate, reach sexual maturity earlier, and attain greater weight-at-length than their same-sex counterparts living in the western North Pacific.

Graham, J. B., Dewar, H., Lai, N. C., Lowell, W. R., & Arce, S. M. (1990). Aspects of Shark Swimming Performance Determined Using a Large Water Tunnel. *Journal of Experimental Biology, 151*(1), 175-192 https://doi.org/10.1242/jeb.151.1.175

A large, sea-going water tunnel was used in various studies of shark swimming performance. The critical swimming velocity (UCTil, an index of aerobically sustainable swimming speed) of a 70 cm long lemon shark (Negaprion brevirostris Poey) was determined to be 1.1 Ls"1 , where L is body length. The Umt of the leopard shark {Triakis semifasciata Girard) was found to vary inversely with body size; from about 1.6Ls- 1 in 30-50cm sharks to 0.6LS"1 in 120cm sharks. Large Triakis adopt ram gill ventilation at swimming speeds between 27 and 60cms"1, which is similar to the speed at which this transition occurs in teleosts. Analyses of tail-beat frequency (TBF) in relation to velocity and body size show that smaller Triakis have a higher TBF and can swim at higher relative speeds. TBF, however, approaches a maximal value at speeds approaching U^, suggesting that red muscle contraction velocity may limit sustained swimming speed. The TBF of both Triakis and Negaprion rises at a faster rate with swimming velocity than does that of the more thunniform mako shark (*Isurus oxyrinchus* Rafinesque). This is consistent with the expectation that, at comparable relative speeds, sharks adapted for efficient swimming should have a lower TBF. The rates of O2 consumption of swimming lemon and mako sharks are among the highest yet measured for elasmobranchs and are comparable to those of cruise-adapted teleosts.

Guil-Guerrero, J. L., Venegas-Venegas, E., Rincon-Cervera, M. A., & Suarez, M. D. (2011). Fatty Acid Profiles of Livers from Selected Marine Fish Species. *Journal of Food Composition and Analysis, 24*(2), 217-222 https://doi.org/10.1016/j.jfca.2010.07.011

Fish livers (FLs) constitute a rich and underexploited source of long-chain polyunsaturated fatty acids (LCPUFAs). Unfortunately, FLs are usually discarded when fish are processed in industrial factories for human consumption, thus the nutritional possibilities of LCPUFAs of FLs is wasted. Nevertheless, these organs might be used as a cheaper source of LCPUFAs. such as eicosapentaenoic (EPA, 20:5n-3), docosahexaenoic (DHA, 22:6n-3) and arachidonic acids (AA, 20:4n-6). In the present work, the FA profiles of FLs of 12 fish species commonly consumed in southern Spain have been determined. The output of the analyses showed that the total FA in FLs ranged between 10.8% in European anchovy to 70.0% in great weaver. FLs from shortfin mako yielded the most unsaturated oil, showing also the higher amount of LCPUFAs (51.4%) and n-3 LCPUFAs (46.3%). FLs from great weever and European anchovy were characterized by a high LCPUFA content. All species show a good n-3/n-6 ratio, with blue whiting (10.2) at the top of the range. Saturated FAs (SFAs) reached the highest amounts in European pilchard (35.8%) and axillary seabream (35.5%). while Mediterranean hake showed the higher amounts of monounsaturated FAs (MUFAs) (50.2%), although LCPUFA content was also noticeable in this species. A remarkable characteristic of FLs confirmed in this work is that this organ constitutes a rich source of n-3 LCPUFA, especially of EPA and DHA.

Hernandez, S., Haye, P. A., & Acuna, E. (2009). Morphological Identification of Fins of the Main Traded Pelagic Shark Species in Chile: Blue Shark (*Prionace glauca* Linnaeus), Shortfin Mako (*Isurus oxyrhinchus* Rafinesque), and Porbeagle (*Lamna nasus* Bonnaterre). *Gayana, 73*(1), 33-39 Retrieved from https://scielo.conicyt.cl/pdf/gayana/v73n1/art05.pdf

The lack of species-specific landing records has produced difficulties in shark stock assessments in Chile. Given that the records are insufficient for fisheries assessments, it is imperative to have trustable morphological characteristics (or the identification of species or parts of their bodies (such as fins). This study describes morphological characters useful for the identification of fins of the three main traded pelagic shark species (P glauca, I. oxyrhinchus and L. nasus). Results showed that there arc diagnostic morphological characters to identify the fins of these three species. Given that the studied species are the most traded ones, the descriptions of the fins and the taxonomic keys per Cut type developed in this study Should be of high use to monitor landings of shark, especially fins in sacs. The knowledge of the proportion of traded species and the quantity of each is important for future fisheries assessments and the establishment of management plans.

Hight, B. V., Holts, D., Graham, J. B., Kennedy, B. P., Taylor, V., Sepulveda, C. A., . . . Lai, N. C. (2007). Plasma Catecholamine Levels as Indicators of the Post-Release Survivorship of Juvenile Pelagic Sharks Caught on Experimental Drift Longlines in the Southern California Bight. *Marine and Freshwater Research, 58*(1), 145-151 https://doi.org/10.1071/mf05260

Between 1983 and 2004, nearly 12 000 shortfin mako (*Isurus oxyrinchus*), common thresher (*Alopias vulpinus*) and blue (*Prionace glauca*) sharks were tagged in the Southern California Bight; however, only 1.97% of these have been returned. One possible reason for this low return rate could be post-release mortality caused by capture stress from the experimental longline. Plasma catecholamine levels were

analysed to evaluate stress levels in longline-captured, rod-and-reel-captured and unstressed docile sharks. The mean catecholamine values determined for the three tag-release species ranged from 6539 to 22 079 pg mL(-1). The level of adrenaline found in moribund *I. oxyrinchus* (94 807 pg mL(-1)) was much higher than in either P. glauca (46 845 pg mL(-1)) or A. vulpinus (36 890 pg mL(-1)). In contrast, blood obtained from sharks that were landed within minutes had lower catecholamine values (P. glauca, 889 and 1347 pg mL(-1); *I. oxyrinchus*, 2960 and 3946 pg mL(-1), adrenaline and noradrenaline respectively). Among the nine *I. oxyrinchus* specimens that were recaptured long after their longline capture and release, the highest adrenaline level measured just before release was 33 352 pg mL(-1). Because these mako sharks survived sufficiently long to be recaptured, their time-of-release catecholamine levels provide a conservative estimate of similar to 80% viability on the longline-captured and released population.

Hueter, R. E., Tyminski, J. P., Morris, J. J., Abierno, A. R., & Valdes, J. A. (2017). Horizontal and Vertical Movements of Longfin Makos (*Isurus paucus*) Tracked with Satellite-Linked Tags in the Northwestern Atlantic Ocean. *Fishery Bulletin, 115*(1), 101-116 https://doi.org/10.7755/Fb.115.1.9

The longfin mako (*Isurus paucus*) is a poorly studied oceanic shark taken in fisheries throughout its worldwide range in temperate and tropical waters. Satellite- linked tags were deployed to investigate the movements of 2 mature males, one tagged in the northeastern Gulf of Mexico (GOM) and the other off northern Cuba. Horizontal tracks estimated by using likelihood methods were similar for these sharks; comparable movements were documented from the GOM, through the Straits of Florida and the Bahamas, and into the open Atlantic Ocean where they converged on the Mid- Atlantic Bight. Depth and temperature ranges were 0- 1767 m and 4.0- 28.8 degrees C. A diel pattern of vertical movement was evident for both individuals, along with regular forays from cold daytime depths to warmer near-surface waters, possibly as an adaptation for thermoregulation. The vertical movements of longfin makos allow them to exploit vertically migrating prey but these movements increase their vulnerability to pelagic longlining. The horizontal movements of these sharks reveal the limited benefit of areas currently closed to pelagic longlining off the southeastern United States and also indicate the connectivity of U.S., Cuban, Mexican, and Bahamian waters for this species. Because of the vulnerability of longfin makos to overexploitation, improved biological information is needed for accurate stock assessments and appropriate management and conservation measures.

Joshima, H., Namaizawa, C., Miyazaki, T., Shiode, D., Yoshida, J., & Nemoto, M. (2020). Fisheries Biology of Blue Sharks in Sagami Bay, Japan. In *Evolution of Marine Coastal Ecosystems under the Pressure of Global Changes.* H. Y. Ceccaldi HJ., Komatsu T., Prouzet P., Sautour B., Yoshida J. (eds) (Ed.), (pp. 193-203): Springer https://doi.org/10.1007/978-3-030-43484-7_14

Blue shark (*Prionace glauca*) and shortfin mako shark (*Isurus oxyrinchus*) are recognized as pelagic sharks and highly migratory species, but these sharks appear in coastal areas. It is suggested that sharks migrate in the growth stage, but we do not know the details and how sharks use coastal areas. A fishing survey of these species in coastal areas like Sagami Bay is rare, and thus we carried out two types of longline operations to survey catch trends about the shark in Sagami Bay from August 2011 to July 2017: vertical and horizontal longline operations. Both species were caught throughout the year, with peaks in July and December for both blue sharks and shortfin mako sharks. Many of the male juvenile blue sharks caught had not reached sexual maturity, and pregnant blue sharks were also present among the

females. The birthing period of blue sharks is reported to be from April to July, and the young are believed to be born and grow up in the open ocean of the North Pacific. However, the fact that we caught pregnant blue sharks close to giving birth suggests that they may give birth in coastal areas such as Sagami Bay. We were unable to catch young shark larvae because of the size selectivity of the longline fishing gear. Future studies, using net sampling, will be necessary to search for new-born blue sharks in this coastal area.

Joung, S. J., & Hsu, H. H. (2005). Reproduction and Embryonic Development of the Shortfin Mako, *Isurus oxyrinchus* Rafinesque, 1810, in the Northwestern Pacific. *Zoological Studies, 44*(4), 487-496 Retrieved from http://zoolstud.sinica.edu.tw/Journals/44.4/487.pdf

Reproduction and embryonic development of the shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, in the northwestern Pacific. Zoological Studies 44(4): 487-496. The reproductive biology of the shortfin mako shark, *Isurus oxyrinchus* Rafinesque, 1810 is described based on 750 females and 498 males (including 24 pregnant females) collected from Oct. 2001 to Mar. 2004 at Nanfangao fish market, northeastern Taiwan. The size at maturity was 210 and 278 cm total length (TL) for males and females, respectively. Size at birth was approximately 74 cm TL, and litter size ranged from 4 to 15, with a mean of 11.1; there was no increase in litter size with maternal size. The mating period is from Jan. to June, and pupping occurs between Dec. and July. We estimated the gestation period to be 23-25 mo and the corresponding reproductive cycle to be 3 yr. Embryos are nourished by oophagy, and develop a grossly distended abdomen as their "yolk stomach" fills with ova. Small embryos, 15-22 cm in TL, are able to swallow egg capsules, but do not yet have teeth. Teeth form in embryos at about 26 cm TL, and they begin shedding at 42 cm TL. A subsequent set of teeth are formed at 61 cm TL. Uterine cannibalism (adelphophagy) occurs occasionally, most likely due to unequal embryonic growth.

Kabasakal, H. (2017). On the Jaws of a Shortfin Mako Shark, *Isurus oxyrinchus*, Caught Off the İzmİr Peninsula (Central Aegean Sea, Turkey). *Annales : Series Historia Naturalis, 27*(2), 151-154 https://doi.org/10.19233/ASHN.2017.18

An old record of shortfin mako shark, *Isurus oxyrinchus*, is discussed based on the set of upper and lower jaws dissected from a specimen caught off the Izmir Peninsula, central Aegean Sea, Turkey, which is now on display at the Kusadasi fish market. The specimen was captured as bycatch by a purse-seiner in the early 1990s. Based on the lower jaw circumference to total length ratio for *I. oxyrinchus*, the total length of this specimen was estimated at 1.8 m.

Kabasakal, H., & Kabasakal, O. (2013). First Record of a Shortfin Mako Shark, *Isurus oxyrinchus* Rafinesque, 1810 (Chondrichthyes: Lamnidae) from the Bay of Saroz (Ne Aegean Sea). *Annales: Series historia naturalis Znanstveno Raziskovalno Sredisce Republike Slovenije., 23*(1), 27 Retrieved from http://old.zdjp.si/sl/docs/annales/naturalis/n23-1/kabasakal-kabasakal.pdf

A male shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, was caught on March 30, 2012, in coastal waters of Bay of Saroz, by a commercial fisherman using hook and line. Total length of the shark was 123.6 cm. This is the first confirmed record of a shortfin mako shark in the aforementioned region. Morphometrics and biological data of the present specimen are reported.

Kai, M., Shiozaki, K., Ohshimo, S., & Yokawa, K. (2015). Growth and Spatiotemporal Distribution of Juvenile Shortfin Mako (*Isurus oxyrinchus*) in the Western and Central North Pacific. *Marine and Freshwater Research, 66*(12), 1176-1190 https://doi.org/10.1071/Mf14316

This paper presents an estimation of growth curves and spatiotemporal distributions of juvenile shortfin mako shark (*Isurus oxyrinchus*) in the western and central North Pacific Ocean using port sampling data collected from 2005 to 2013. The monthly length compositions show a clear transition of three modes in the size range of smaller than 150-cm precaudal length (PCL), which were believed to represent the growth of age-0 to age-2 classes, and they were then decomposed into age groups by fitting a Gaussian mixture distribution. Simulation data of lengths at monthly ages were generated from the mean and standard deviation of each distribution, and fit with a von Bertalanffy growth function. Parameters of the estimated growth curves for males and females were 274.4 and 239.4cm PCL for the asymptotic length and 0.19 and 0.25 year(-1) for the growth coefficient indicating apparently faster growth than previously reported. Generalised linear models were applied to age-0 to explore the seasonal changes of PCL by area. They were born during late autumn and winter off the coast of north-eastern Japan, an area known to have relatively high productivity compared with other pelagic areas, and gradually expanded their habitat eastward and northward with the seasons as they grew.

Kim, S. B., Ji, C. I., Woo, J. W., Do, J. R., Cho, S. M., Lee, Y. B., . . . Park, J. H. (2012). Simplified Purification of Chondroitin Sulphate from Scapular Cartilage of Shortfin Mako Shark (*Isurus oxyrinchus*). *International Journal of Food Science and Technology, 47*(1), 91-99 https://doi.org/10.1111/j.1365-2621.2011.02811.x

Chondroitin sulphate (ChS) from the scapular cartilage of the shortfin mako shark (*Isurus oxyrinchus*) was purified by two-stage enzymatic hydrolysis and a fractional precipitation process using isopropyl alcohol. Characteristics of the ChS fraction were investigated using cellulose acetate membrane electrophoresis and FT-IR spectra. A maximum hydrolysis rate of 78.26% was achieved with 1.35% (w/w) Alcalase and 1.20% (w/w) Flavourzyme. A minimum nitrogen content of 2.89% was obtained with 1.43% (w/w) Alcalase and 1.33% (w/w) Flavourzyme, as determined by response surface methodology. The precipitation of ChS from the enzymatic hydrolysates was optimised at 40% (v/v) isopropyl alcohol, which contained 2% (w/v) NaCl to lower the nitrogen content. The precipitate was further purified via membrane filtration (molecular-weight cut-off, 3 kDa) to remove salt and low-molecular-weight materials. The ChS purified by enzymatic hydrolysis, isopropyl alcohol precipitation and membrane filtration was identified as ChS C by electrophoresis and FT-IR spectra.

Kinney, M. J., Wells, R. J., & Kohin, S. (2016). Oxytetracycline Age Validation of an Adult Shortfin Mako Shark *Isurus oxyrinchus* after 6 Years at Liberty. *Journal of Fish Biology, 89*(3), 1828-1833 https://doi.org/10.1111/jfb.13044

This study presents findings on an oxytetracycline injected adult male shortfin mako *Isurus oxyrinchus* recaptured in waters off of southern California after 6 years at liberty. During the period at liberty, the vertebral band-pair deposition rate was validated at one per year. This result indicates that from a time at or near sexual maturity, male *I. oxyrinchus* in the north-east Pacific Ocean exhibit a band-pair deposition rate of one band pair per year, while deposition rates for juveniles in the area have been validated at two band pairs per year.

Kneebone, J., Natanson, L. J., Andrews, A. H., & Howell, W. H. (2008). Using Bomb Radiocarbon Analyses to Validate Age and Growth Estimates for the Tiger Shark, Galeocerdo Cuvier, in the Western North Atlantic. *Marine Biology, 154*(3), 423-434 https://doi.org/10.1007/s00227-008-0934-y

Refined and validated age and growth determinations are necessary for a proper understanding of tiger shark (*Galeocerdo cuvier*) life history characteristics in the western North Atlantic (WNA). Age and growth estimates were derived from band counts of 238-sectioned vertebral centra. Bomb radiocarbon analysis of ten band pairs extracted from four vertebral sections suggested that band pairs are deposited annually up to age 20. Males and females were aged to 20 and 22 years, respectively, although longevity estimates predict maximum ages of 27 and 29 years, respectively. Two- and three-parameter von Bertalanffy and Gompertz growth functions fit to length at age data demonstrated that growth rates were similar for males and females up to around 200 cm fork length (FL) after which male growth slowed. Both sexes appear to reach maturity at age 10. The two-parameter von Bertalanffy growth function provided the best biological fit to length at age data generating parameter estimates of: L-infinity = 330 cm FL, k = 0.131 for males and L-infinity = 347 cm FL, k = 0.124 for females, with L-0 set at 62 cm FL. This study provides a rigorous description of tiger shark age and growth in the WNA and further demonstrates the utility of bomb radiocarbon as an age validation tool for elasmobranch fish.

Lai, N. C., Lankin, K., & Holts, D. (2004, Mar 23). *Cardiovascular Properties of Two Oceanic Elasmobranchs, the Shortfin Mako Shark (Isurus oxyrinchus) and the Pelagic Ray (Dasyatis Violacea).* Paper presented at the Experimental Biology 2004 Meeting, Washington, D.C. Retrieved from https://faseb.onlinelibrary.wiley.com/hub/journal/15306860/homepage/meetingabstracts

No abstract.

Lai, N. C., Korsmeyer, K. E., Katz, S., Holts, D. B., Laughlin, L. M., & Graham, J. B. (1997). Hemodynamics and Blood Properties of the Shortfin Mako Shark (*Isurus oxyrinchus*). *Copeia*(2), 424-428 https://doi.org/10.2307/1447765

Lamnid sharks are difficult experimental subjects, and knowledge of their cardiovascular system has been largely based on morphological (Tota et al., 1983; Emery et al., 1985), histological (Sanchez-Quintana and Hurle, 1987; De Andres et al., 1990), biochemical (Farrell and Davie, 1991; Dickson et al., 1993), and hematological investigations (Wells and Davie, 1985; Emery, 1986). Because these sharks have a physiological capacity that exceeds other species (Graham et al., 1990), it is important to obtain cardiovascular data in living specimens. This report details in vivo studies of the cardiovascular and blood respiratory properties and the heart regulatory mechanism of shortfin mako sharks (*Isurus oxyrinchus*) carried out at sea on freshly collected specimens, most of which were subsequently released.

Lai, N. C., Dalton, N., Holts, D., Graham, J. B., Kwong, C., Rasmussen, R., & Lai, Y. Y. (2002, Mar 22). *Ventricular Diastolic Function in the Shortfin Mako Sharks*. Retrieved from https://faseb.onlinelibrary.wiley.com/hub/journal/15306860/homepage/meetingabstracts

No abstract.

Lang, A., Motta, P., Habegger, M. L., & Hueter, R. (2012). Shark Skin Boundary Layer Control. In *Natural Locomotion in Fluids and on Surfaces.* (pp. 139-150) https://doi.org/10.1007/978-1-4614-3997-4_9

An investigation into the separation control mechanisms found on the skin of fast-swimming sharks, with a particular focus on the shortfin mako (*Isurus oxyrinchus*) which is considered to be one of the fastest pelagic shark species, was carried out. Previous researchers have reported a bristling capability of the scales, or denticles, in certain species of sharks. This study identified that bristling angle is highly dependent on body location, with some scales easily erectable to angles in excess of 50◦. The flexibility of the scale appears to be due to a reduction in the size of the base of the scale where anchored into the skin. It is hypothesized that the scales act as a passive, flow-actuated mechanism as a means of controlling flow separation.

Lang, A., Motta, P., Habegger, M. L., Hueter, R., & Afroz, F. (2011). Shark Skin Separation Control Mechanisms. *Marine Technology Society Journal, 45*(4), 208-215 https://doi.org/10.4031/Mtsj.45.4.12

Drag reduction by marine organisms has undergone millions of years of natural selection, and from these organisms biomimetic studies can derive new technologies. The shortfin mako (*Isurus oxyrinchus*), considered to be one of the fastest and most agile marine predators, is known to have highly flexible scales on certain locations of its body. This scale flexibility is theorized to provide a passive, flow-actuated mechanism for controlling flow separation and thereby decreasing drag. Recent biological observations have found that the shortfin mako has highly flexible scales, bristling to angles in excess of 50 degrees, particularly on the sides of the body downstream of the gills. High "contragility," which is explicitly defined here as the ability to change or move in a new or opposing direction while already in a turn, would occur if form drag were minimized. This would thus indicate the potential control of flow separation on body regions aft of the point of maximum girth or in regions of adverse pressure gradient. Thus results are consistent with the hypothesis that scale bristling controls flow separation. This scale flexibility appears to be a result of a reduction in the relative size of the base of the scales as well as a reorganization of the base shape as evidenced by histological examination of the skin and scales. Probable mechanisms leading to separation control are discussed.

Lang, A., Afroz, F., Motta, P., Wilroy, J., Wahidi, R., Elliott, C., . . . Asme. (2017). *Sharks, Dolphins and Butterflies: Micro-Sized Surfaces Have Macro Effects*. https://doi.org/10.1115/FEDSM2017-69221

Sharks, dolphins and butterflies swim and fly in different flow regimes, yet the structure of their surfaces interacting with the surrounding fluid all appear to contain very important microscopic features that lead to reduced drag and increased flying or swimming efficiency. Sharks have moveable scales (approximately 200 microns in size) that act as a passive, flow actuated dynamic roughness for separation control. Water tunnel experiments with real shortfin mako shark skin samples mounted to models have shown significant control of flow separation in both laminar and turbulent boundary layer

scenarios. Dolphins have sinusoidal-shaped millimeter-sized, transverse grooves covering a large percentage of their body. Experiments show that similar geometries embedded in a turbulent boundary layer can lead to separation control at the slight expense of increased friction drag. Alternatively, butterfly scales (100 microns in size covering the wings in a roof shingle pattern) appear to fundamentally alter the local skin friction drag depending on flow orientation for what is dominantly a laminar boundary layer interacting with the wings. However, in this case the surface may also slow the growth and formation of the leading-edge vortex and these effects shown in experiments may help explain a mean decrease in climbing efficiency (joules per flap) of 37.8% for live butterflies once their scales were removed. An overview of these results is discussed for these three cases, bringing out the importance of finding solutions in nature for essential engineering problems.

Lang, A. W., Bradshaw, M. T., Smith, J. A., Wheelus, J. N., Motta, P. J., Habegger, M. L., & Hueter, R. E. (2014). Movable Shark Scales Act as a Passive Dynamic Micro-Roughness to Control Flow Separation. *Bioinspiration & Biomimetics, 9*(3), 036017 https://doi.org/10.1088/1748-3182/9/3/036017

Shark scales on fast-swimming sharks have been shown to be movable to angles in excess of 50 degrees, and we hypothesize that this characteristic gives this shark skin a preferred flow direction. During the onset of separation, flow reversal is initiated close to the surface. However, the movable scales would be actuated by the reversed flow thereby causing a greater resistance to any further flow reversal and this mechanism would disrupt the process leading to eventual flow separation. Here we report for the first time experimental evidence of the separation control capability of real shark skin through water tunnel testing. Using skin samples from a shortfin mako *Isurus oxyrinchus*, we tested a pectoral fin and flank skin attached to a NACA 4412 hydrofoil and separation control was observed in the presence of movable shark scales under certain conditions in both cases. We hypothesize that the scales provide a passive, flow-actuated mechanism acting as a dynamic micro-roughness to control flow separation.

Liu, K.-M., Tsai, W.-P., & Su, K.-Y. (2021). *Updated Size Composition of Shortfin Mako Shark Caught by the Taiwanese Tuna Longline Fishery in the North Pacific Ocean*. Paper presented at the ISC/21/SHARKWG-1. Webinar Retrieved from http://isc.fra.go.jp/reports/shark/shark_2021_1.html

There are two types of Taiwanese tuna longline vessels, namely the large-scale tuna longline vessels (LTLL, ≧100 GRT) and the small-scale tuna longline vessels (STLL, ＜100 GRT). In the present study, the size data of the shortfin mako shark caught by these two fisheries are presented. All size data recorded in other measurements were converted to pre-caudal length (PCL) by using the converting equations available. The size of shortfin mako caught by the Taiwanese STLL from 1989-2019 in the North Pacific ranged from 61 to 338 cm PCL for females (n = 116,281), and 60–262 cm PCL for males (n = 108,505). The sizes of 11,173 individuals (sexes combined) recorded in the logbook of LTLL from 2005-2019 ranged from 61 to 303 cm PCL. Two modes (mostly 100 and 150 cm PCL) were observed in the size distribution of shortfin mako shark caught by the STLL in the North Pacific Ocean. This also implied that the catches comprised mostly immature fish (female < 228, male < 172 cm PCL). The capture of high proportion of immature sharks may have serious impact on the sustainability of the fishery.

Liu, K. M., Sibagariang, R. D., Joung, S. J., & Wang, S. B. (2018). Age and Growth of the Shortfin Mako Shark in the Southern Indian Ocean. *Marine and Coastal Fisheries, 10*(6), 577-589 https://doi.org/10.1002/mcf2.10054

The Shortfin Mako *Isurus oxyrinchus* is one of the major shark bycatch species in the longline fishery for tuna Thunnus spp. in the Indian Ocean; however, its biological information is still little known. This study estimated the age and growth of Shortfin Makos in the southern Indian Ocean. In total, 178 specimens (72 females and 106 males) were opportunistically collected by the scientific observers onboard Taiwanese large-scale longline fishing vessels from February 2013 to September 2016 in the southern Indian Ocean. The relationship of gutted weight (GW; in kg) to curved fork length (CFL; in cm) for both sexes combined was estimated as GW = 0.00001 x CFL2.517 (n = 170, r(2) = 0.85). Growth band pairs (including translucent and opaque bands) were counted based on sectioned vertebral centra from the caudal peduncle region. The periodicity of band-pair deposition on vertebral centra was estimated to be 1 year, with opaque bands deposited around August based on edge analysis. On this basis, the maximum observed ages of females and males were 18 and 14 years, respectively. The von Bertalanffy growth function best fitted the observed sexes-combined length-at-age data, with growth parameter estimates as L-infinity = 267.6 cm CFL, k = 0.123/year, and t(0) = -2.487 years (n = 159). The growth model could be improved for future stock assessments by increasing the sample size, particularly on very small (neonates and small subadults) and very large female Shortfin Makos.

Liu, K. M., Wu, C. B., Joung, S. J., Tsai, W. P., & Su, K. Y. (2021). Multi-Model Approach on Growth Estimation and Association with Life History Trait for Elasmobranchs. *Frontiers in Marine Science, 8* https://doi.org/10.3389/fmars.2021.591692

Age and growth information is essential for stock assessment of fish, and growth model selection may influence the accuracy of stock assessment and subsequent fishery management decision making. Previous descriptions of the age and growth of elasmobranchs relied mainly on the von Bertalanffy growth model (VBGM). However, it has been noted that sharks, skates and rays exhibit significant variety in size, shape, and life history traits. Given this variation, the VBGM may not necessarily provide the best fit for all elasmobranchs. This study attempts to improve the growth estimates by using multi-model approach to test four growth models-the VBGM, the two-parameter VBGM, the Robertson (Logistic) and the Gompertz models to fit observed or simulated length-at-age data for 38 species (44 cases) of elasmobranchs. The best-fit growth model was selected based on the bias corrected Akaike's Information Criterion (AICc), the AICc difference, the AICc weight, the Bayesian Information Criterion (BIC), and the Leave-one-out cross-validation (LOOCV). The VBGM and two-parameter VBGM provide the best fit for species with slow growth and extended longevity (L-infinity > 100 cm TL, 0.02 < k < 0.25 yr(-1)), such as pelagic sharks. For fast-growing small sharks (L-infinity < 100 cm TL, k(r) or k(g) > 0.2 yr(-1)) in deep waters and for smallsized demersal skates/rays, the Robertson and the Gompertz models provide the best fit. The best-fit growth models for small sharks in shallow waters are the two-parameter VBGM and the Robertson model. Although it was found that the best-fit growth models for elasmobranchs were associated with their life history trait, exceptions were also noted. Therefore, a multi-model approach incorporating with the best-fit model selected for each group in this study was recommended in growth estimation for elasmobranchs.

Lopez-Mirones, F., de Maddalena, A., & Van Buiten, R. S. (2020). On a Huge Shortfin Mako Shark *Isurus oxyrinchus* Rafinesque, 1810 (Chondrichthyes: Lamnidae) Observed at Cabrera Grande, Balearic

Islands, Spain. *Annales : Series Historia Naturalis, 30*(1), 25-30 https://doi.org/http://dx.doi.org/10.19233/ASHN.2020.04

A huge female shortfin mako shark, *Isurus oxyrinchus*, was observed on 28 June 2018 near Cabrera Grande, in the Balearic Islands, Spain. Its total length was carefully estimated at 500 cm based on a comparison with a 520-cm inflatable boat. This specimen is therefore the largest mako known alive and the second largest mako ever recorded worldwide.

Lopez-Romero, F. A., Klimpfinger, C., Tanaka, S., & Kriwet, J. (2020). Growth Trajectories of Prenatal Embryos of the Deep-Sea Shark Chlamydoselachus Anguineus (Chondrichthyes). *Journal of Fish Biology, 97*(1), 212-224 https://doi.org/10.1111/jfb.14352

Chlamydoselachus anguineus, Garman 1884, commonly called the frilled shark, is a deep-sea shark species occurring up to depths of 1300 m. It is assumed to represent an ancient morphotype of sharks (e.g., terminal mouth opening, more than five gill slits) and thus is often considered to represent plesiomorphic traits for sharks. Therefore, its early ontogenetic developmental traits are important for understanding the evolution of its particular phenotype. Here, we established six stages for prenatal embryos and used linear measurements and geometric morphometrics to analyse changes in shape and size as well as their timing during different embryonic stages. Our results show a change in head shape and a relocation of the mouth opening at a late stage of development. We also detected a negative allometric growth of the head and especially the eye compared to the rest of the body and a sexual dimorphism in total body length, which differs from the known data for adults. A multivariate analysis of covariance shows a significant interaction of shape related to the logarithm of centroid size and developmental stage. Geometric morphometrics results indicate that the head shape changes as a covariate of body size while not accounting for differences between sexes. The growth pattern of stages 32 and 33 indicates a shift in head shape, thus highlighting the moment in development when the jaws start to elongate anteriorly to finally achieve the adult condition of terminal mouth opening rather than retaining the early embryonic subterminal position as is typical for sharks. Thus, the antero-terminal mouth opening of the frilled shark has to be considered a derived feature.

Maia, A., Queiroz, N., Cabral, H. N., Santos, A. M., & Correia, J. P. (2007). Reproductive Biology and Population Dynamics of the Shortfin Mako, *Isurus oxyrinchus* Rafinesque, 1810, Off the Southwest Portuguese Coast, Eastern North Atlantic. *Journal of Applied Ichthyology, 23*(3), 246-251 https://doi.org/10.1111/j.1439-0426.2007.00849.x

A total of 262 shortfin mako sharks, *Isurus oxyrinchus*, was sampled from the swordfish longliners operating in the eastern North Atlantic. Most were juveniles, with only 3.4% mature. Based on cohort analysis, average growth was determined as 61.1 cm year(-1) for the first year and 40.6 cm year(-1) for the second year. There was a marked seasonality in growth, with average monthly rates of 5.0 cm month(-1) in summer and 2.1 cm month(-1) in winter. Cohort analysis also indicated summer as the probable parturition season, with sharks close to birth size caught in May 2003 and July 2004. Length at maturity for males was estimated at 180-cm fork length using the Schnute model. No females between 210 and 290-cm fork length were caught, although this appears to be the interval where maturation occurs. Gear selectivity was considered as the probable cause for the low number of mature females sampled.

McClusky, L. M., & Sulikowski, J. (2016). A Comparative Study of Intratesticular Ductules in the Spermatogenically Active Testes of Shortfin Mako and Thresher Sharks. *Anat Rec (Hoboken), 299*(10), 1435-1448 https://doi.org/10.1002/ar.23456

This comparative study of the radial testes of sexually mature thresher sharks (*Alopias vulpinus*) and shortfin mako sharks (*Isurus oxyrinchus*) describes the histology of the three-tiered network of sperm-carrying ductules in the testis and the lymphomyeloid tissue associated with it, namely the epigonal organ. In both species, a testis --> epigonal gradient was evident regarding the thickness of the ductule epithelial lining and subepithelial investment of connective tissue. Ductules straddling the testis-epigonal border often displayed luminal leukocytes and various signs of regression, including the progressive thickening of the ductule epithelial lining, dissolution of the cytoplasm, and loss of normal histoarchitecture. In Isurus, large amorphous areas formed due to the fusion of neighboring regressing ductules. The epigonal organ of Alopias additionally revealed circular degenerative sperm-containing, Hassall-like bodies with either a degenerate or cellular appearance, the latter the result of cell proliferative activity (as shown by proliferating cell nuclear antigen (PCNA) immunohistochemistry) in an expanding outer border comprising cells with intensely PCNA immunoreactive slender and oblong nuclei. The latter cells exhibited a periphery-to-center transformation of their nuclei, at which stage they were PCNA-negative and most likely in a terminally differentiated state as they phagocytized the cell debris in the degenerate core. Intermediate stages of these circular bodies were a rarity. The relationship between these degenerate bodies, and the common occurrence of blind pockets in the epithelial linings and non-apoptosis-related degenerate patches in the apical cytoplasmic regions of the irregular shaped ductules in Alopias is unclear, and needs further elucidation.

Mejuto, J., Ramos-Cartelle, A., Quintans, M., González, F., & Carroceda, A. (2008). Length-Weight Relationships and Morphometric Conversion Factors between Weights for the Blue Shark (*Prionace glauca*) and Shortfin Mako (*Isurus oxyrinchus*) Caught by the Spanish Surface Longline Fleet in the Atlantic Ocean. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 62*(5), 1494-1507 Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.556.9812&rep=rep1&type=pdf

Length-weight relationships and conversion factors between different weight types are presented for the blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) which are the two of the most prevalent by-catch species in the surface longline fleets. The conversion factors RW-GW and RW-DW obtained for blue shark range, respectively, from 1.1946-1.2219 and 2.4074-2.5052 and from 1.15251.1577 and 1.4369-1.4575 for shortfin mako. Linear equations for conversion between different weight types are also presented for both species. The predicted weights from length-weight relationships obtained using nonlinear modeling do not differ from some of the previous length-weight relationships reported by other authors for both species.

Merlino, A., Vergara, A., & Vitagliano, L. (2014). Comments on Structural Studies of Haemoglobin from Pisces Species Shortfin Mako Shark (*Isurus oxyrinchus*) at 1.9 a Resolution by P. Ramesh Et Al. (2013). J. Synchrotron Rad.20, 843-847. *J Synchrotron Radiat, 21*(Pt 4), 832-833 https://doi.org/10.1107/S1600577514010170

No abstract.

Mirlean, N., Ferraz, A. H., Seus-Arrache, E. R., Andrade, C. F. F., Costa, L. P., & Johannesson, K. H. (2019). Mercury and Selenium in the Brazilian Subtropical Marine Products: Food Composition and Safety. *Journal of Food Composition and Analysis, 84*, 103310 https://doi.org/10.1016/j.jfca.2019.103310

In this study we estimate the content of mercury (Hg) and selenium (Se) in 32 fish and 6 shellfish species that represent the most intensively caught, consumed, and exported seafood species from the Brazilian subtropics. The mean Hg contents in three species of large carnivorous fish (i.e., shortfin mako; 502 mu g kg(-1); dusky grouper, 789 mu g kg(-1); school shark, 806 mu gkg(-1)) were above the allowable limit (500 mu g kg(-1)) for human consumption. However, the content of Se in the fin fish, as well as the shellfish, were substantially below (147 mu gkg(-1) <= Se <= 688 mu gkg(-1)) what is considered safe for human consumption (i.e., 2000 mu gkg(-1)). The only exception was in the deep-sea red crab sample, which exhibited an elevated Se content of ca. 5400 mu g kg(-1). Nevertheless, all studied species had mean Se:Hg molar ratios greater than 1:1, suggesting that human consumption of the studied sea food species are relatively safe with respect to their Hg content. The highest Se:Hg molar ratios were found in the shellfish species investigated, as well as the most sought after commercial fish. The calculated Se health benefit value index (Se-HBV, HBVSe), which is a qualitative measure of the ability of Se to mute the toxic effects of Hg, exhibited high positive values in most of the studied fish species, suggesting human consumption of these species was safe. An exception was sardine, an important species for producing canned fish, which exhibited the lowest HBV.

Mollet, H. F., Cliff, G., Pratt, H. L., & Stevens, J. D. (2000). Reproductive Biology of the Female Shortfin Mako, *Isurus oxyrinchus* Rafinesque, 1810, with Comments on the Embryonic Development of Lamnoids. *Fishery Bulletin, 98*(2), 299-318 Retrieved from https://spo.nmfs.noaa.gov/content/reproductive-biology-female-shortfin-mako-isurus-oxyrinchus-rafinesque-1810-comments

Reproductive data from 95 mature female shortfin mako sharks, *Isurus oxyrinchus* Rafinesque, 1810, including 35 pregnant females, together with data on 450 postnatal fish were collected from around the world. Size at birth was approximately 70 cm total length (TL) and litter size varied from 4 to 25. increasing with maternal size. Embryo length-at-capture data predicted a gestation period of 15-18 months and late winter to midspring parturition in both hemispheres. A temporal analysis of uterus width index and gonadosomatic index of pregnant and postpartum females indicated that the reproductive cycle is three years. The median TL-at-maturity of females from the western North Atlantic (2.98 m) was greater than that of females from the Southern Hemisphere (2.73 m) and they were 16-19% heavier in the TL range of 2.5-3.5 m. Recently ovulated females and a litter with 2.6-3.3 cm TL embryos having external gills, a large yolk sac, and still inside their egg cases, are described. We describe a litter of embryos (52.0 cm TL) with huge yolk-filled stomachs. Litters of 59.9- and 68.8-cm-TL embryos showed a decline in the mass of the yolk-filled stomach from 29.1% to 10.9% of total mass and an increase in hepatosomatic indices from 3.7% to 7.0% as gestation advances. When the mass of the yolk-filled stomach was excluded, the mass-length relationship of shortfin mako embryos could be fitted with a power regression similar to that for postnatal fish. The condition factor of lamnid embryos (including yolk-stomach mass) reaches a maximum between 20 and 35 kg/m(3) when the embryos are midterm and have the largest yolk stomachs. The condition factor of alopiid embryos remains constant, indicating that no large yolk-filled stomach develops.

Motta, P., Habegger, M. L., Lang, A., Hueter, R., & Davis, J. (2012). Scale Morphology and Flexibility in the Shortfin Mako *Isurus oxyrinchus* and the Blacktip Shark Carcharhinus Limbatus. *J Morphol, 273*(10), 1096-1110 https://doi.org/10.1002/jmor.20047

We quantified placoid scale morphology and flexibility in the shortfin mako *Isurus oxyrinchus* and the blacktip shark Carcharhinus limbatus. The shortfin mako shark has shorter scales than the blacktip shark. The majority of the shortfin mako shark scales have three longitudinal riblets with narrow spacing and shallow grooves. In comparison, the blacktip shark scales have five to seven longitudinal riblets with wider spacing and deeper grooves. Manual manipulation of the scales at 16 regions on the body and fins revealed a range of scale flexibility, from regions of nonerectable scales such as on the leading edge of the fins to highly erectable scales along the flank of the shortfin mako shark body. The flank scales of the shortfin mako shark can be erected to a greater angle than the flank scales of the blacktip shark. The shortfin mako shark has a region of highly flexible scales on the lateral flank that can be erected to at least 50 degrees . The scales of the two species are anchored in the stratum laxum of the dermis. The attachment fibers of the scales in both species appear to be almost exclusively collagen, with elastin fibers visible in the stratum laxum of both species. The most erectable scales of the shortfin mako shark have long crowns and relatively short bases that are wider than long. The combination of a long crown length to short base length facilitates pivoting of the scales. Erection of flank scales and resulting drag reduction is hypothesized to be passively driven by localized flow patterns over the skin.

Nakano, H., & Nagasawa, K. (1996). Distribution of Pelagic Elasmobranchs Caught by Salmon Research Gillnets in the North Pacific. *Fisheries Science, 62*(6), 860-865 https://doi.org/10.2331/fishsci.62.860

The distribution of pelagic elasmobranchs was analyzed using by catch data from the high seas salmon surveys by research gillnets from 1981 to 1991 in the North Pacific Ocean and the Bering Sea. Five species of sharks and one stingray were reported. Blue and salmon sharks and spiny dogfish were dominant and constituted 98% of the total shark catch. It is considered that the research area includes the southern part of the distribution for spiny dogfish and salmon sharks and the northern part of that for blue, shortfin mako, cookiecutter sharks and pelagic stingrays. These elasmobranchs showed spatial segregation by species in distribution according to oceanographic conditions. Intraspecific sexual and growth dependent segregations were also confirmed. Length frequency distributions of blue and salmon sharks suggest that their nursery grounds exist around the transitional domain of the subarctic boundary.

Natanson, L. J., & Deacy, B. M. (2019). Using Oxytetracycline Validation for Confirmation of Changes in Vertebral Band-Pair Deposition Rates with Ontogeny in Sandbar Sharks (Carcharhinus Plumbeus) in the Western North Atlantic Ocean. *Fishery Bulletin, 117*(1-2), 50-58 https://doi.org/10.7755/Fb.117.1.6

Age underestimation of many shark species, such as the sandbar shark (Carcharhinus plumbeus), has been proven with age validation methods including bomb radiocarbon dating, oxytetracycline (OTC) injection, and tag-recapture data. Validation studies indicate that band-pair deposition in vertebral centra may not be directly related to time, especially in older individuals of a species. In this study,

vertebrae from tagged, OTC-injected, and recaptured sandbar sharks were examined to determine if band-pair deposition past the OTC mark matched time at liberty. In 6 of 8 OTC-injected sharks at liberty for >1 year, band-pair count past the OTC mark underestimated time at liberty by 24-58%. Additionally, growth rates derived from tag-recapture data were slower than those described by previously published vertebral band-pair growth curves but were similar to those predicted by previous bomb radiocarbon dating and OTC results from this study. Together, the results from these studies indicate that modeling tag-recapture data may be more accurate for age determination in elasmobranchs given that band-pair counts on vertebral centra do not coincide with age throughout life. Analyses indicate that sandbar sharks may be less productive than previously understood.

Natanson, L. J., Kohler, N. E., Ardizzone, D., Cailliet, G. M., Wintner, S. P., & Mollet, H. F. (2006). Validated Age and Growth Estimates for the Shortfin Mako, *Isurus oxyrinchus*, in the North Atlantic Ocean. *Environmental Biology of Fishes, 77*(3-4), 367-383 https://doi.org/10.1007/s10641-006-9127-z

Age and growth estimates for the shortfin mako, *Isurus oxyrinchus*, derived from vertebral centra of 258 specimens (118 males, 140 females), ranging in size from 64 to 340 cm fork length (FL) were compared with data from 22 tag-recaptured individuals (74-193 cm FL) and length-frequency data from 1822 individuals (1035 males, 787 females; 65-215 cm FL). Annual band-pair deposition, confirmed by a concurrent bomb radiocarbon validation study, was used as the basis for band interpretation. Validation was further confirmed with a tetracycline-injected male shortfin mako recaptured after being at liberty off South Africa for 1 year and aged at 18 years. Growth rates from tag-recapture analysis (GROTAG) were higher than those derived from vertebral annuli and were only available from sharks up to 193 cm FL at recapture. Modal length-frequency data were used to verify the first four age classes. Growth curves were fit using both von Bertalanffy and Gompertz models. The 3-parameter version of the von Bertalanffy growth function produced the most biologically reasonable values for males, based on observed data (L-infinity = 253 cm FL, K = 0.125 year(-1) (estimated longevity = 21 year), and L-0 = 72 cm). The 3-parameter version of the Gompertz growth function produced the most biologically reasonable estimates, for females (L-infinity = 366 cm FL, K = 0.087 year(-1) (estimated longevity = 38 year) and L (0) = 88 cm. Males and females were aged to 29 (260 cm FL) and 32 years (335 cm FL), respectively. Both sexes grew similarly to age 11 (207 cm FL, 212 cm FL for males and females, respectively) when the curve leveled in males and continued to rise in females. Age at 50% maturity was estimated at 8 years for males (185 cm FL) and 18 years for females (275 cm FL). The species grows slower, matures later and has a longer life span than previously reported in North Atlantic waters.

Natanson, L. J., Skomal, G. B., Hoffmann, S. L., Porter, M. E., Goldman, K. J., & Serra, D. (2018). Age and Growth of Sharks: Do Vertebral Band Pairs Record Age? *Marine and Freshwater Research, 69*(9), 1440-1452 https://doi.org/10.1071/mf17279

Inaccurate age estimates can have severe consequences in the management of elasmobranchs. Numerous studies in shark age validation have demonstrated a disconnect between band pair counts and age, resulting in age underestimation, particularly in older individuals. To investigate the relationship between band pairs, vertebral shape and growth, we quantified intracolumn differences in centrum morphology (size and structure) and band pair counts in seven shark species: Squatina dumeril, *Carcharodon carcharias*, *Lamna nasus*, *Isurus oxyrinchus*, *Alopias vulpinus*, *Prionace glauca* and Carcharhinus obscurus. In all species examined, band pair deposition was closely related to body girth

and the structural properties of the cartilaginous skeleton, relative to maximum size, and body type. These results have strong implications for accurately assessing age for fisheries management of these species.

Natanson, L. J., Winton, M., Bowlby, H., Joyce, W., Deacy, B., Coelho, R., & Rosa, D. (2020). Updated Reproductive Parameters for the Shortfin Mako (*Isurus oxyrinchus*) in the North Atlantic Ocean with Inferences of Distribution by Sex and Reproductive Stage. *Fishery Bulletin, 118*(1), 21-36 https://doi.org/10.7755/Fb.118.1.3

Prompted by recent concern about the stock status of the short-fin mako (*Isurus oxyrinchus*) in the North Atlantic Ocean, we examined reproductive data from 731 individuals (351 females and 380 males) collected by 3 scientific organizations to improve estimates of size and age at maturity. Males ranged in size from 70 to 283 cm fork length (FL) and females from 71 to 338 cm FL. Females matured between 263 and 291 cm FL, with an estimated median length at maturity (L-50) of 280 cm FL and a median weight at maturity (WT50) of 275 kg. Males matured between 173 and 187 cm FL, with an L-50 of 182 cm FL and WT50 of 64 kg. Catch records from 4 international programs were also examined to investigate spatiotemporal variation in the distribution of life history stages based on updated size-at-maturity estimates and to identify potential parturition and nursery grounds. These records identified the Gulf of Mexico and the eastern North Atlantic Ocean off Portugal as birthing and nursery areas, with the most important nursery area occurring in the western North Atlantic Ocean.

Newbrey, M. G., Siversson, M., Cook, T. D., Fotheringham, A. M., & Sanchez, R. L. (2015). Vertebral Morphology, Dentition, Age, Growth, and Ecology of the Large Lamniform Shark Cardabiodon Ricki. *Acta Palaeontologica Polonica, 60*(4), 877-897 https://doi.org/10.4202/app.2012.0047

Cardabiodon ricki and Cardabiodon venator were large lamniform sharks with a patchy but global distribution in the Cenomanian and Turonian. Their teeth are generally rare and skeletal elements are less common. The centra of Cardabiodon ricki can be distinguished from those of other lamniforms by their unique combination of characteristics: medium length, round articulating outline with a very thick corpus calcareum, a corpus calcareum with a laterally flat rim, robust radial lamellae, thick radial lamellae that occur in low density, concentric lamellae absent, small circular or subovate pores concentrated next to each corpus calcareum, and papillose circular ridges on the surface of the corpus calcareum. The large diameter and robustness of the centra of two examined specimens suggest that Cardabiodon was large, had a rigid vertebral column, and was a fast swimmer. The sectioned corpora calcarea show both individuals deposited 13 bands (assumed to represent annual increments) after the birth ring. The identification of the birth ring is supported in the holotype of Cardabiodon ricki as the back-calculated tooth size at age 0 is nearly equal to the size of the smallest known isolated tooth of this species. The birth ring size (5-6.6 mm radial distance [RD]) overlaps with that of Archaeolamna kopingensis (5.4 mm RD) and the range of variation of Cretoxyrhina mantelli (6-11.6 mm RD) from the Smoky Hill Chalk, Niobrara Formation. The revised, reconstructed lower jaw dentition of the holotype of Cardabiodon ricki contains four anterior and 12 lateroposterior files. Total body length is estimated at 5.5 m based on 746 mm lower jaw bite circumference reconstructed from associated teeth of the holotype.

Newton, K. C., Wraith, J., & Dickson, K. A. (2015). Digestive Enzyme Activities Are Higher in the Shortfin Mako Shark, *Isurus oxyrinchus*, Than in Ectothermic Sharks as a Result of Visceral Endothermy. *Fish Physiol Biochem, 41*(4), 887-898 https://doi.org/10.1007/s10695-015-0055-8

Lamnid sharks are regionally endothermic fishes that maintain visceral temperatures elevated above the ambient water temperature. Visceral endothermy is thought to increase rates of digestion and food processing and allow thermal niche expansion. We tested the hypothesis that, at in vivo temperatures, the endothermic shortfin mako shark, *Isurus oxyrinchus*, has higher specific activities of three digestive enzymes-gastric pepsin and pancreatic trypsin and lipase-than the thresher shark, *Alopias vulpinus*, and the blue shark, *Prionace glauca*, neither of which can maintain elevated visceral temperatures. Homogenized stomach or pancreas tissue obtained from sharks collected by pelagic longline was incubated at both 15 and 25 degrees C, at saturating substrate concentrations, to quantify tissue enzymatic activity. The mako had significantly higher enzyme activities at 25 degrees C than did the thresher and blue sharks at 15 degrees C. This difference was not a simple temperature effect, because at 25 degrees C the mako had higher trypsin activity than the blue shark and higher activities for all enzymes than the thresher shark. We also hypothesized that the thermal coefficient, or Q 10 value, would be higher for the mako shark than for the thresher and blue sharks because of its more stable visceral temperature. However, the mako and thresher sharks had similar Q 10 values for all enzymes, perhaps because of their closer phylogenetic relationship. The higher in vivo digestive enzyme activities in the mako shark should result in higher rates of food processing and may represent a selective advantage of regional visceral endothermy.

Ohshimo, S., Fujinami, Y., Shiozaki, K., Kai, M., Semba, Y., Katsumata, N., . . . Yokawa, K. (2016). Distribution, Body Length, and Abundance of Blue Shark and Shortfin Mako Offshore of Northeastern Japan, as Determined from Observed Pelagic Longline Data, 2000-2014. *Fisheries Oceanography, 25*(3), 259-276 https://doi.org/10.1111/fog.12149

Longline surveys have been conducted in the Northwest Pacific Ocean from 2000 to 2014 using chartered commercial longline vessels. Each year, two cruises were conducted offshore of northeastern Japan from mid-April to mid-June. For each longline set during the surveys, onboard scientists collected detailed biological information about the species caught, such as the size and sex, and recorded the catch numbers for all species. Blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) have eurythermal distributions, but the application of a generalized additive model (GAM) showed that the sea surface temperatures (SSTs) at catch sites positive for shortfin mako were warmer than those for blue shark. On the basis of the GAM, the probabilities of occurrence of both sharks differed by size category: small sharks had a narrower SST range than that of large sharks. Most catches of both sharks were juveniles, and the nominal catch rate of blue shark was more than 10 times that of shortfin mako. The standardized catch per unit effort (CPUE) for both species was calculated using a generalized linear model (GLM) with negative binomial errors, or a delta-lognormal GLM. The standardized CPUE for blue shark in the second quarter of the year peaked in the mid-2000s and then decreased, but it has been increasing since 2012. The CPUE for shortfin mako in the second quarter generally increased, with fluctuations.

Okamura, H., & Semba, Y. (2009). A Novel Statistical Method for Validating the Periodicity of Vertebral Growth Band Formation in Elasmobranch Fishes. *Canadian Journal of Fisheries and Aquatic Sciences, 66*(5), 771-780 https://doi.org/10.1139/F09-039

A simple age verification method is presented for centrum edge analysis (CEA) of elasmobranch species. In this method, a binomial model is linked with a von Mises distribution for circular data, taking the characteristics of the CEA data into account. The periodicity of growth band pairs is categorized as no cycle, an annual cycle, or a biannual cycle. Three models are then constructed according to different periodicities. We use the Akaike information criterion (AIC) to determine which model is the best. The models were applied to the shortfin mako shark (*Isurus oxyrinchus*) data collected in the North Pacific to identify the best periodicity model. The AIC best-fitting model was one involving an annual cycle. The general performance of the method was evaluated using simulated data of various sample sizes, formation times, and durations of growth band pairs. The simulation trials showed that the performance of the method was satisfactory with moderate sample sizes. This method should improve the accuracy of age determination and could be applied to all species that have periodic growth band pairs.

Oliveira, P., Hazin, F. H., Carvalho, F., Rego, M., Coelho, R., Piercy, A., & Burgess, G. (2010). Reproductive Biology of the Crocodile Shark Pseudocarcharias Kamoharai. *Journal of Fish Biology, 76*(7), 1655-1670 https://doi.org/10.1111/j.1095-8649.2010.02606.x

From February 2005 to September 2007, a total of 490 crocodile sharks Pseudocarcharias kamoharai, caught as by-catch in the swordfish and tuna longline fishery that operates in the tropical western Atlantic Ocean, was studied in regard to their reproductive biology. Maximum observed total lengths (L(T)) were 1220 and 1090 mm for females and males respectively, with a high proportion of the catch being composed of mature specimens. Sexual maturity was attained at 760-810 mm L(T) for males (L(T50) = 800 mm) and 870-980 mm L(T) for females (L(T50) = 916 mm). The size at birth was estimated at 415 mm L(T). Temporal variation in gonad morphology and mass suggests that in this region P. kamoharai, an aplacental viviparous species with oophagy, does not show a well-defined reproductive seasonality, with mating and parturition occurring possibly over an extended period of the year. Mean +/-S.D. fecundity was estimated to be 3.9 (+/- 0.6) pups per reproductive cycle.

Patricia, F. W., Guzman, D., Inigo, B., Urtzi, I., Maria, B. J., & Manu, S. (2019). Morphological Characterization and Hydrodynamic Behavior of Shortfin Mako Shark (*Isurus oxyrinchus*) Dorsal Fin Denticles. *Journal of Bionic Engineering, 16*(4), 730-741 https://doi.org/10.1007/s42235-019-0059-7

The shortfin mako shark (*Isurus oxyrinchus*) is one of the fastest marine fishes, reaching speeds of up to 70 kmh(-1). Their speed is related to the skin surface design composed of dermal denticles. Denticles vary in size and shape according to placement on the body and minimize turbulence around the body. The objective of this study is to analyze the interaction between seawater flow and denticles on the dorsal fin. High-resolution microscopy (scanning electron microscopy and confocal microscopy) were used to measure defined parts of the dermal denticles. These measurements, along with ratios based on length-to-width define three morphologies (rounded, semi-rounded, long) that were 3D reconstructed. Computational fluid dynamics simulated fluid passage over reconstructed denticles and describe hydrodynamic efficiency under different conditions. An increase in angle of inclination produced a relevant increase in the drag coefficient, especially for high velocity inlets. The lowest drag coefficient values were found in long and semi-rounded, followed by rounded morphologies. The hydrodynamic behavior of shark skin demonstrates a relation to the morphological characteristics of dermal denticles

on the dorsal fin. It is concluded that the best hydroefficiency relies on the rounded morphology and may serve to design hydrodynamically efficient surfaces or manmade assemblies.

Pepperell, J. G. (1992). Trends in the Distribution, Species Composition and Size of Sharks Caught by Gamefish Anglers Off South-Eastern Australia, 1961-90. *Australian Journal of Marine and Freshwater Research, 43*(1), 213-225 https://doi.org/10.1071/Mf9920213

Records of shark captures were extracted from the archives of 10 of the major New South Wales gamefishing clubs that operate from ports located between latitudes 33-degrees-S and 37-degrees-S. Although organized game fishing began off eastern Australia in 1936, the majority of catches were made after 1960. Data normally recorded by these clubs included common name of shark, whole weight, locality of capture, boat name and angler. Recognized single species of sharks recorded by these clubs were blue (*Prionace glauca*), tiger (Galeocerdo cuvier), white (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrinchus*) and grey nurse (Carcharias taurus). Species identified only to generic level, and recorded by clubs, were whalers or requiem sharks (Carcharhinus spp.), hammerheads (Sphyrna spp.) and threshers (Alopias spp.). Analysis of catch records indicated that the mako shark was the most common species caught overall, although whaler sharks dominated the catch in the northern part of the study area and hammerhead sharks dominated the catch in the south. Grey nurse and white sharks were relatively rare in the southern part of the study area. Whaler sharks dominated the catch in the 1960s, and the proportions of blue and tiger sharks in the catch increased in the 1980s. Size ranges and distributions of some species also varied through time and by area. Some of the observed changes could be attributed to changed fishing practices, particularly the increasing popularity of tag-and-release and an increasing tendency to fish further from the coast. A marked decline in the number and proportion of white sharks in the catch since the 1970s gives cause for some concern regarding the status of that species off south-eastern Australia.

Perry, C. N., Cartamil, D. P., Bernal, D., Sepulveda, C. A., Theilmann, R. J., Graham, J. B., & Frank, L. R. (2007). Quantification of Red Myotomal Muscle Volume and Geometry in the Shortfin Mako Shark (*Isurus oxyrinchus*) and the Salmon Shark (*Lamna ditropis*) Using T1-Weighted Magnetic Resonance Imaging. *J Morphol, 268*(4), 284-292 https://doi.org/10.1002/jmor.10516

T1-weighted magnetic resonance imaging (MRI) in conjunction with image and segmentation analysis (i.e., the process of digitally partitioning tissues based on specified MR image characteristics) was evaluated as a noninvasive alternative for differentiating muscle fiber types and quantifying the amounts of slow, red aerobic muscle in the shortfin mako shark (*Isurus oxyrinchus*) and the salmon shark (*Lamna ditropis*). MRI-determinations of red muscle quantity and position made for the mid-body sections of three mako sharks (73.5-110 cm fork length, FL) are in close agreement (within the 95% confidence intervals) with data obtained for the same sections by the conventional dissection method involving serial cross-sectioning and volumetric analyses, and with previously reported findings for this species. The overall distribution of salmon shark red muscle as a function of body fork length was also found to be consistent with previously acquired serial dissection data for this species; however, MR imaging revealed an anterior shift in peak red muscle cross-sectional area corresponding to an increase in body mass. Moreover, MRI facilitated visualization of the intact and anatomically correct relationship of tendon linking the red muscle and the caudal peduncle. This study thus demonstrates that MRI is effective in acquiring high-resolution three-dimensional digital data with high contrast between different fish tissue types. Relative to serial dissection, MRI allows more precise quantification of the

position, volume, and other details about the types of muscle within the fish myotome, while conserving specimen structural integrity.

Pratt Jr, H. L., & Casey, J. G. (1983). Age and Growth of the Shortfin Mako, *Isurus oxyrinchus*, Using Four Methods. *Canadian Journal of Fisheries and Aquatic Sciences, 40*(11), 1944-1957 https://doi.org/10.1139/f83-224

Age and growth rate of shortfin mako, *I. oxyrinchus* , captured by hook and line between 1961 and 1981 were determined using four methods: temporal analysis of length - month information, results of tagging data, length - frequency analysis, and ring counts on vertebrae. A temporal analysis of length - month information relating size to age for individuals less than 150 cm fork length was used to determine size, time of birth, and early growth rate. This growth rate was used as a basis for interpreting the accuracy of other methods. Males and females had a similar growth rate even though females grow much larger than males.

Ramesh, P., Sundaresan, S. S., Sathya Moorthy, P., Balasubramanian, M., & Ponnuswamy, M. N. (2013). Structural Studies of Haemoglobin from Pisces Species Shortfin Mako Shark (*Isurus oxyrinchus*) at 1.9 a Resolution. *J Synchrotron Radiat, 20*(Pt 6), 843-847 https://doi.org/10.1107/S0909049513021572

Haemoglobin (Hb) is a tetrameric iron-containing protein that carries oxygen from the lungs to tissues and carbon dioxide from tissues back to the lungs. Pisces are the advanced aquatic vertebrates capable of surviving at wide depth ranges. The shortfin mako shark (SMS) is the pelagic, largest, fastest and most sophisticated species of the shark kingdom with well developed eyes. Mostly the pisces species are cold blooded in nature. Distinctly, the SMSs are warm-blooded animals with an advanced circulatory system. SMSs are capable of maintaining elevated muscle temperatures up to 33 K above the ambient water temperatures at a depth of 150-500 m. SMSs have a diverged air-breathing mechanism compared with other vertebrates. The haemoglobin molecule consists of four polypeptide chains, namely two alpha chains, each with 140 amino acids and two beta chains each having 136 amino acids. The SMS Hb was found to crystallize in monoclinic space group P21 using the hanging-drop vapour-diffusion method at room temperature. The crystal packing parameters for the SMS Hb structure contain one whole biological molecule in the asymmetric unit with a solvent content of 47%. The SMS Hb quaternary structural features interface-interface interactions and heme binding sites are discussed with different state Hbs and the results reveal that SMS Hb adopts an unliganded deoxy T state conformation.

Ramesh, P., Sundaresan, S. S., Sathya Moorthy, P., Balasubramanian, M., & Ponnuswamy, M. N. (2014). Response to Comments on Structural Studies of Haemoglobin from Pisces Species Shortfin Mako Shark (*Isurus oxyrinchus*) at 1.9 a Resolution by P. Ramesh Et Al. (2013). J. Synchrotron Rad. 20, 843-847. *J Synchrotron Radiat, 21*(Pt 4), 834 https://doi.org/10.1107/S1600577514010285

No abstract.

Rangel, B. D., Salmon, T., Poscai, A. N., Kfoury, J. R., & Rici, R. E. G. (2019). Comparative Investigation into the Morphology of Oral Papillae and Denticles of Four Species of Lamnid and Sphyrnid Sharks. *Zoomorphology, 138*(1), 127-136 https://doi.org/10.1007/s00435-018-0427-6

The microstructures of the oral cavity in sharks have received relatively little study, despite their potential functional importance for gustation, feeding, and ventilation. Accordingly, here we conducted a preliminary comparative investigation into the structure and organization of oral papillae and denticles found on the ventral surface of the oral cavity in four species of shark (bigeye thresher, shortfin mako, scalloped hammerhead, and smooth hammerhead). Despite a limited sample size, differences in complexity and ornamentation of oral papillae and denticles were found across the four species. The scalloped hammerhead shark exhibited the largest oral papillae compared to the bigeye thresher and the shortfin mako. The most complex oral denticles, in terms of number of ridges and microstructures, were found in the scalloped hammerhead, followed by the bigeye thresher, smooth hammerhead and shortfin mako. For smooth hammerheads, in which samples were available from both juveniles and adults, differences in denticle microstructures were found suggesting possible ontogenetic variations. These results suggest that shape, size and arrangement of oral papillae and denticles may be related to ecology and phylogeny of the species studied. Based on these emerging patterns we discuss several plausible hypotheses relating to the function of these structures for consideration in future studies.

Saidi, B., Bradai, M. N., Bouain, A., Guelorget, O., & Capape, C. (2005). Capture of a Pregnant Female White Shark, Carcharodon Carcharias (Lamnidae) in the Gulf of Gabes (Southern Tunisia, Central Mediterranean) with Comments on Oophagy in Sharks. *Cybium, 29*(3), 303-307 https://doi.org/10.26028/cybium/2005-293-008

A pregnant female white shark, Carcharodon carcharias, was captured by a tunny boat in the Gulf of Gabes (southern Tunisia, central Mediterranean), on 26 February 2004. The four developing embryos, three females and one male, ranged between 132 and 135 cm total length and weighed between 27.65 and 31.50 kg. The embryos exhibited a distended abdomen due to yolk accumulation. This confirms that the species is oophagous. Oophagy during embryonic development is commented, with emphasis on white shark, porbeagle, *Lamna nasus*, shortfin mako, *Isurus oxyrhinchus* and bigeye threshershark, *Alopias superciliosus*.

Schnetz, L., Kriwet, J., & Pfaff, C. (2017). Virtual Reconstruction of the Skeletal Labyrinth of Two Lamnid Sharks (Elasmobranchii, Lamniformes). *Journal of Fish Biology, 90*(3), 1083-1089 https://doi.org/10.1111/jfb.13219

The first virtual reconstruction of the skeletal labyrinth of the porbeagle shark *Lamna nasus* and the shortfin mako shark *Isurus oxyrinchus* is presented here using high-resolution micro-computed tomography. The results, in comparison with previously published information, suggest relationships between skeletal labyrinth morphology and locomotion mode in chondrichthyans, but also show that further studies are required to establish such connections. Nevertheless, this study adds to the knowledge of the skeletal labyrinth morphology in two apex elasmobranch species.

Semba, Y., Aoki, I., & Yokawa, K. (2011). Size at Maturity and Reproductive Traits of Shortfin Mako, *Isurus oxyrinchus*, in the Western and Central North Pacific. *Marine and Freshwater Research, 62*(1), 20-29 https://doi.org/10.1071/Mf10123

Shortfin mako, *Isurus oxyrinchus*, is a highly migratory shark with a worldwide distribution. Despite recent global concern and intensive ecological studies on this species, little is known about its reproduction, owing to a paucity of information on mature females. We investigated the size-at-maturity and reproductive traits of shortfin mako in the western and central North Pacific. Males attain maturity at a much smaller size (156 cm) than females (256 cm). The positive relationship between maternal size and litter size indicates that fecundity increases as the female grows. The seasonal trends in the gonadosomatic index of mature individuals and the presence of females in early pregnancy confirmed that mating occurs from spring to summer. From monthly changes in embryonic body lengths, averaged per litter, and the seasonal occurrence of neonates, we infer that parturition occurs from winter to spring and the gestation period is 9-13 months. There was a negative correlation between embryonic developmental stages and environmental temperature for females in various stages of pregnancy. The productivity of this species may be higher than previously thought, considering the estimated gestation period and size-related fecundity.

Sepulveda, C. A., Graham, J. B., & Bernal, D. (2007). Aerobic Metabolic Rates of Swimming Juvenile Mako Sharks, *Isurus oxyrinchus*. *Marine Biology, 152*(5), 1087-1094 https://doi.org/10.1007/s00227-007-0757-2

The shortfin mako shark, *Isurus oxyrinchus*, is a highly streamlined epipelagic predator that has several anatomical and physiological specializations hypothesized to increase aerobic swimming performance. A large swim-tunnel respirometer was used to measure oxygen consumption (MO2) in juvenile mako sharks (swimming under controlled temperature and flow conditions) to test the hypothesis that the mako shark has an elevated maintenance metabolism when compared to other sharks of similar size swimming at the same water temperature. Specimen collections were conducted off the coast of southern California, USA (32.94 degrees N and 117.37 degrees W) in 2001-2002 at sea-surface temperatures of 16.0-21.0 degrees C. Swimming MO2 and tail beat frequency (TBF) were measured for nine mako sharks [77-107 cm in total length (TL) and 4.4 to 9.5 kg body mass] at speeds from 28 to 54 cm s(-1) (0.27-0.65 TL s(-1)) and water temperatures of 16.5-19.5 degrees C. Standard metabolic rate (SMR) was estimated from the extrapolation to 0-velocity of the linear regression through the LogMO(2) and swimming speed data. The estimated LogSMR (+/- SE) for the pooled data was 2.0937 +/- 0.058 or 124 mg O-2 kg(-1) h(-1). The routine metabolic rate (RMR) calculated from seventeen MO2 measurements from all specimens, at all test speeds was (mean +/- SE) 344 +/- 22 mg O-2 kg(-1) h(-1) at 0.44 +/- 0.03 TL s(-1). The maximum metabolic rate (MMR) measured for any one shark in this study was 541 mg O-2 kg(-1) h(-1) at 54 cm s(-1) (0.65 TL s(-1)). The mean (+/- SE) TBF for 39 observations of steady swimming at all test speeds was 1.00 +/- 0.01 Hz, which agrees with field observations of 1.03 +/- 0.03 Hz in four undisturbed free-swimming mako sharks observed during the same time period. These findings suggest that the estimate of SMR for juvenile makos is comparable to that recorded for other similar-sized, ram-ventilating shark species (when corrected for differences in experimental temperature). However, the mako RMR and MMR are apparently among the highest measured for any shark species.

Shimada, K. (2002). Teeth of Embryos in Lamniform Sharks (Chondrichthyes : Elasmobranchii). *Environmental Biology of Fishes, 63*(3), 309-319 https://doi.org/10.1023/A:1014392211903

The dentitions of lamniform sharks possess a unique heterodonty, the lamnoid tooth pattern. However. in embryos, there are 'embryonic' and 'adult' dentitions. The teeth in the embryonic dentition are peg-like and appear to be attached to the jaw in an acrodont fashion. The adult dentition is characterized by the presence of replacement tooth series with the lamnoid tooth pattern. The embryonic-adult transition in dentitions appears at around 30-60 cm TL. Tooth replacement generally begins before birth in embryos with adult dentitions. The adult dentition becomes functional just before or after parturition. An embryo of one species (*Lamna nasus*) shows a tooth directly on the symphysis of the upper jaws, marking the first record of a medial tooth for the order Lamniformes.

Smale, M. J. (1996). Cephalopods as Prey .4. Fishes. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 351*(1343), 1067-1081 https://doi.org/10.1098/rstb.1996.0094

Predatory fishes that consume cephalopods have broad spectrum diets that include other groups, such as fishes and crustaceans. Extremely few fish predators feed on cephalopods to the virtual exclusion of other prey, although the tawny nurse shark Nebrius ferrugineus and the sicklefin weasel shark Hemigaleus microstoma may be exceptions, and some deep-living spiny dogfish may feed largely on cephalopods when they are available. Cephalopods are rarely taken in estuaries but they become more important prey on continental shelves and squids may be more dominant prey during their spawning aggregations. Cephalopods generally become more important components of the diets of larger predatory fishes, such as sharks, that inhabit the continental slope and rise. They may be important to pelagic fishes, such as swordfish and tunas in some parts of the oceans. Cephalopods are rarely taken by benthic Antarctic fishes but they are important prey of some pelagic fishes in the Arctic. Abundance and size of potential prey is critical, and the behaviour of both predator and potential prey is decisive, in prey choice. Factors such as prey switching with growth, between areas and at different times, have major influences on the diets of predators. There are extremely few studies that obtain rigorous enough data to allow quantitative analysis of the significance of cephalopods (or other prey) in the diets of predatory fishes and even the most comprehensive studies are not predictive because findings relate only to the time period of each study. Nevertheless, cephalopods are important components of most marine food webs and, furthermore, may play an indirect role in facilitating prey capture to secondary predators, and in providing rejecta to benthic scavengers.

Staudinger, M. D., Juanes, F., Salmon, B., & Teffer, A. K. (2013). The Distribution, Diversity, and Importance of Cephalopods in Top Predator Diets from Offshore Habitats of the Northwest Atlantic Ocean. *Deep-Sea Research Part Ii-Topical Studies in Oceanography, 95*, 182-192 https://doi.org/10.1016/j.dsr2.2012.06.004

Large pelagic predators were used as biological samplers to gain information on cephalopod diversity, abundance, distribution, and their role as prey in the Northwest Atlantic Ocean. Fish predators were caught by recreational anglers in offshore waters of New England (NE; 2007-2010), the Mid-Atlantic Bight (MAB; 2009-2010) and the South Atlantic Bight (SAB; 2010-2011). In total, 2362 cephalopods, including 22 species of squid and 4 octopods, were identified in the diets of 13 species of predatory fishes. Cephalopod body sizes were obtained for 1973 specimens through direct measurement of

mantle lengths (ML) or estimated using lower rostral/hood lengths of lower beaks. Cephalopod diversity (number of species) was highest in predator diets from the SAB (N=19), intermediate in NE (N=18), and lowest in the MAB (N=9); however, differences may reflect unequal sampling effort among regions. The most important cephalopods across predator diets by number and frequency of occurrence were from the families Ommastrephidae, Argonautidae, Loliginidae, and Histioteuthidae. Shortfin squid (Illex illecebrosus) and paper nautilus (Argonauta sp.) were the most recurrent species identified across spatiotemporal scales; size distributions of these two species varied significantly among regions, and the largest individuals on average were found in the MAB. Results demonstrate that although pelagic predators consumed a broad range of cephalopod species, octopods and squids from the families Argonautidae and Ommastrephidae dominated the collective diets of numerous pelagic teleosts and elasmobranchs, and play a key role in offshore food-webs of the Northwest Atlantic Ocean. This study emphasizes the value of using predators as biological samplers to gain information on cephalopod biogeography, and as a potential approach to track ecosystem changes in this region due to environmental and anthropogenic stressors.

Stevens, J. D. (2008). The Biology and Ecology of the Shortfin Mako Shark, *Isurus oxyrinchus*. In *Sharks of the Open Ocean.* E. K. P. M. D. Camhi, E. A. Babcock (Ed.), (pp. 87-94): Blackwell Publishing Ltd. https://doi.org/10.1002/9781444302516.ch7

The shortfi n mako (*Isurus oxyrinchus*) is a pelagic oceanic species with a widespread distribution in temperate and tropical waters of all the world's oceans. It is a target species in some areas, but is principally caught as bycatch of longline and gill-net fi sheries directed at tuna and billfi sh. It is also an important recreational species in many regions. Reproduction is by aplacental viviparity with embryonic oophagy, and the average litter size is 12; captures of pregnant females are relatively uncommon. Breeding frequency appears to be every 3 years, giving an annual fecundity of four. There is a large sexual difference in the size at maturity, with males maturing at about 195 cm total length, while females do not mature until 265–280 cm. Published information on growth rates and age estimates are confl icting, and further studies are required to resolve age and growth in this species. Little is known about stock structure or population status, although most populations do not (yet) appear to have been severely impacted by fi shing pressure.

Tamburin, E., Amador-Capitanachi, M. J., Galvan-Magana, F., Norris, T. A., & Elorriaga-Verplancken, F. R. (2020). Isotopic Variation in Blood Components Based on Their Biochemistry and Physiology: A Comparison between Sharks and Fur Seals. *J Exp Zool A Ecol Integr Physiol, 333*(2), 104-110 https://doi.org/10.1002/jez.2330

Research using stable isotopes analysis (SIA) of carbon (delta(13) C) and nitrogen (delta(15) N) in blood components is lacking, because of the challenge of sample collection, processing, and storage in remote areas. There also is a paucity of information regarding the effect of tissue biochemical composition on isotopic ratios with few comparisons among taxa. We collected blood samples from shortfin mako sharks (n = 70; 2016) and Guadalupe fur seals (n = 25; 2017). All samples were centrifuged to obtain plasma from sharks and serum from the Guadalupe fur seals, and all the samples were prepared for SIA and analyzed using a Costech 4010 elemental analyzer interfaced with a Delta V Plus isotope ratio mass spectrometer. We found significant differences between plasma delta(13) C values of shortfin mako sharks (-17.6 +/- 0.9 per thousand) and serum of Guadalupe fur seals (-20.3 +/- 1.2 per thousand), but we did not find any differences for delta(15) N values between the two species. The differences in

delta(13) C values between species are probably due to the specific blood composition and to the different biochemical characteristics and different adaptations within taxa. These findings highlight the importance of further research on the influence of biochemistry features on isotopic results, in this way a more accurate assessment will be possible for this factor, separating it from the dietary influences on stable isotopic values.

Tomita, T., Miyamoto, K., Kawaguchi, A., Toda, M., Oka, S. I., Nozu, R., & Sato, K. (2017). Dental Ontogeny of a White Shark Embryo. *J Morphol, 278*(2), 215-227 https://doi.org/10.1002/jmor.20630

Unlike most viviparous vertebrates, lamniform sharks develop functional teeth during early gestation. This feature is considered to be related to their unique reproductive mode where the embryo grows to a large size via feeding on nutritive eggs in utero. However, the developmental process of embryonic teeth is largely uninvestigated. We conducted X-ray microcomputed tomography to observe the dentitions of early-, mid-, and full-term embryos of the white shark *Carcharodon carcharias* (Lamniformes, Lamnidae). These data reveal the ontogenetic change of embryonic dentition of the species for the first time. Dentition of the early-term embryos (approximately 45 cm precaudal length, PCL) is distinguished from adult dentition by 1) the presence of microscopic teeth in the distalmost region of the paratoquadrate, 2) a fang-like crown morphology, and 3) a lack of basal concavity of the tooth root. The "intermediate tooth" of early-term embryos is almost the same size as the adjacent teeth, suggesting that lamnoid-type heterodonty (lamnoid tooth pattern) has not yet been established. We also discovered that mid-term embryos (approximately 80 cm PCL) lack functional dentition. Previous studies have shown that the maternal supply of nutritive eggs in lamnoid sharks ceases during mid- to late-gestation. Thus, discontinuation of functional tooth development is likely associated with the completion of the oophagous (egg-eating) phase. Replacement teeth in mid-term embryos include both embryonic and adult-type teeth, suggesting that the embryo to adult transition in dental morphology occurs during this period.

Varghese, S. P., Unnikrishnan, N., Gulati, D. K., & Ayoob, A. E. (2017). Size, Sex and Reproductive Biology of Seven Pelagic Sharks in the Eastern Arabian Sea. *Journal of the Marine Biological Association of the United Kingdom, 97*(1), 181-196 https://doi.org/10.1017/S0025315416000217

Studies on reproduction in sharks are important for their management, since the attainment of sexual maturity has a substantial impact on their distribution, behaviour and biology. However, reproductive biology of large oceanic sharks is poorly studied in the Indian seas. In this study, the size structure, sex and maturity of pelagic thresher (*Alopias pelagicus*), bigeye thresher (A. superciliosus), oceanic whitetip shark (*Carcharhinus longimanus*), tiger shark (Galeocerdo cuvier), shortfin mako (*Isurus oxyrinchus*), longfin mako (*I. paucus*) and blue shark (*Prionace glauca*) in the eastern Arabian Sea are described based on 1449 specimens collected from gillnet-cum-longline landings at the Cochin fisheries harbour during 2013 - 2014. Sex ratios of sampled specimens were biased to males in pelagic thresher, bigeye thresher, tiger shark and blue shark, while females dominated in the specimens of oceanic whitetip shark. Females matured at greater lengths than males in all species except oceanic whitetip shark. Lengths at maturity for males were in the range of 189.05 - 286.56 cm, whereas those of females were in the range of 187.74 - 310.69 cm. Litter sizes of both the thresher shark species were always two, while in oceanic whitetip shark, litter size was 3 - 9 and 22 - 51 in tiger shark. Seasonal reproduction was noticed in

oceanic whitetip shark and tiger shark. Pregnant females were not found in the blue shark, shortfin and longfin makos sampled during the study period. Reproductive aspects of pelagic thresher, bigeye thresher, oceanic whitetip shark, tiger shark, shortfin mako, longfin mako and blue sharks in the eastern Arabian Sea are generally consistent with earlier reports from other regions of the world's oceans. These preliminary findings should be useful to identify suitable management measures for the above shark species.

Vas, P., Stevens, J. D., Bonwick, G. A., & Tizini, O. A. (1990). Cd, Mn, and Zn Concentrations in Vertebrae of Blue Shark and Shortfin Mako in Australian Coastal Waters. *Marine Pollution Bulletin, 21*(4), 203-206 https://doi.org/10.1016/0025-326x(90)90503-Z

The blue shark (*Prionace glauca*) and the shortfin mako (*Isurus oxyrinchus*) are large pelagic predators. Both species occur regularly off the Australian coast. Little is known of their trace metal content in these waters. A single cervical vertebra was selected from the same location from each shark, and was analysed for Mn, Cd, and Zn using atomic absorption spectrophotometry, following wet digestion with HNO sub(3) and HClO sub(4). With low sample numbers for each sex, the results were pooled for analysis, and thus no distinction was made between male and female specimens for either species.

Watson, R. R., & Dickson, K. A. (2001). Enzyme Activities Support the Use of Liver Lipid-Derived Ketone Bodies as Aerobic Fuels in Muscle Tissues of Active Sharks. *Physiol Biochem Zool, 74*(2), 273-282 https://doi.org/10.1086/319667

Few data exist to test the hypothesis that elasmobranchs utilize ketone bodies rather than fatty acids for aerobic metabolism in muscle, especially in continuously swimming, pelagic sharks, which are expected to be more reliant on lipid fuel stores during periods between feeding bouts and due to their high aerobic metabolic rates. Therefore, to provide support for this hypothesis, biochemical indices of lipid metabolism were measured in the slow-twitch, oxidative (red) myotomal muscle, heart, and liver of several active shark species, including the endothermic shortfin mako, *Isurus oxyrinchus*. Tissues were assayed spectrophotometrically for indicator enzymes of fatty acid oxidation (3-hydroxy-o-acyl-CoA dehydrogenase), ketone-body catabolism (3-oxoacid-CoA transferase), and ketogenesis (hydroxy-methylglutaryl-CoA synthase). Red muscle and heart had high capacities for ketone utilization, low capacities for fatty acid oxidation, and undetectable levels of ketogenic enzymes. Liver demonstrated undetectable activities of ketone catabolic enzymes but high capacities for fatty acid oxidation and ketogenesis. Serum concentrations of the ketone beta-hydroxybutyrate varied interspecifically (means of 0.128-0.978 micromol mL(-1)) but were higher than levels previously reported for teleosts. These results are consistent with the hypothesis that aerobic metabolism in muscle tissue of active sharks utilizes ketone bodies, and not fatty acids, derived from liver lipid stores.

Wegner, N. C., & Cartamil, D. P. (2012). Effects of Prolonged Entanglement in Discarded Fishing Gear with Substantive Biofouling on the Health and Behavior of an Adult Shortfin Mako Shark, *Isurus oxyrinchus*. *Marine Pollution Bulletin, 64*(2), 391-394 https://doi.org/10.1016/j.marpolbul.2011.11.017

A mature male shortfin mako, *Isurus oxyrinchus*, was captured with a three-strand twisted natural fiber rope wrapped around the body causing deep abrasions, scoliosis of the back, and undernourishment.

Fifty-two pelagic peduculate barnacles from four species were found fouling on the rope. Assuming larval settlement occurred following entanglement, barnacle growth-rate data suggest the rope had been around the shark for at least 150 days. However, the onset of severe scoliosis (likely linked to the increased constriction of the rope with growth and the added drag induced by biofouling) indicates that this rope may have been in place much longer. Following removal of the rope, a pop-up satellite archival tag was attached to the shark to assess post-release health. The resulting 54 days of tag deployment data show that despite its injuries, the shark survived, and following an initial stress period, exhibited movement patterns characteristic of healthy makos.

Wegner, N. C., Sepulveda, C. A., & Graham, J. B. (2005). Gill Specializations of the Shortfin Mako, *Isurus oxyrinchus*, a Lamnid Shark. *Integrative and Comparative Biology, 45*(6), 1094-1094 Retrieved from https://www.jstor.org/stable/i405179

The tunas (family Scombridae) and the lamnid sharks (family Lamnidae) demonstrate a remarkable convergence for high performance swimming. Increased aerobic muscle power, continuous swimming, and regional endothermy, characteristic of these two groups, mandate the specialization of respiratory structure and function to meet increased oxygen demands. This study provides the first comprehensive analysis oflamnid gill structure in comparison to that of tunas. Vascular plastic replica casts of mako shark gills reveal microvascular modifications to increase lamellar gas transfer. Mako lamellae have diagonal blood-flow channels (previously documented only in tunas and billfishes) that are thought to manage blood pressure drop across long lamellae. Blood is delivered to these oblique channels through an additional outer marginal channel on the lamellar lateral edge, and blood is collected by inner marginal channels. Mako diffusion distances are also quite short; lamellar thickness and lamellar wall width (the blood-water barrier distance) are comparable to measurements obtained for tunas and are among the smallest recorded for comparably sized fish. These microvascular specializations were not found in the blue shark (a non-lamnid). This study also confirms that mako gill surface areas are greater than non-lamnid shark species, but significantly less than those of tunas. The basic elasmobranch respiratory design (which exhibits a much more tortuous water pathway than that of teleosts) may limit lamnid gill surface areas and serve as a bottleneck preventing these sharks from reaching the scope of sustainable aerobic performance achieved by tunas.

Wegner, N. C., Lai, N. C., Bull, K. B., & Graham, J. B. (2012). Oxygen Utilization and the Branchial Pressure Gradient During Ram Ventilation of the Shortfin Mako, *Isurus oxyrinchus*: Is Lamnid Shark-Tuna Convergence Constrained by Elasmobranch Gill Morphology? *Journal of Experimental Biology, 215*(Pt 1), 22-28 https://doi.org/10.1242/jeb.060095

Ram ventilation and gill function in a lamnid shark, the shortfin mako, *Isurus oxyrinchus*, were studied to assess how gill structure may affect the lamnid-tuna convergence for high-performance swimming. Despite differences in mako and tuna gill morphology, mouth gape and basal swimming speeds, measurements of mako O(2) utilization at the gills (53.4+/-4.2%) and the pressure gradient driving branchial flow (96.8+/-26.1 Pa at a mean swimming speed of 38.8+/-5.8 cm s(-1)) are similar to values reported for tunas. Also comparable to tunas are estimates of the velocity (0.22+/-0.03 cm s(-1)) and residence time (0.79+/-0.14 s) of water though the interlamellar channels of the mako gill. However, mako and tuna gills differ in the sites of primary branchial resistance. In the mako, approximately 80% of the total branchial resistance resides in the septal channels, structures inherent to the elasmobranch gill that are not present in tunas. The added resistance at this location is compensated by a correspondingly

lower resistance at the gill lamellae accomplished through wider interlamellar channels. Although greater interlamellar spacing minimizes branchial resistance, it also limits lamellar number and results in a lower total gill surface area for the mako relative to tunas. The morphology of the elasmobranch gill thus appears to constrain gill area and, consequently, limit mako aerobic performance to less than that of tunas.

Wegner, N. C., Sepulveda, C. A., Olson, K. R., Hyndman, K. A., & Graham, J. B. (2010). Functional Morphology of the Gills of the Shortfin Mako, *Isurus oxyrinchus*, a Lamnid Shark. *J Morphol, 271*(8), 937-948 https://doi.org/10.1002/jmor.10845

This study examines the functional gill morphology of the shortfin mako, *Isurus oxyrinchus*, to determine the extent to which its gill structure is convergent with that of tunas for specializations required to increase gas exchange and withstand the forceful branchial flow induced by ram ventilation. Mako gill structure is also compared to that of the blue shark, *Prionace glauca*, an epipelagic species with lower metabolic requirements and a reduced dependence on fast, continuous swimming to ventilate the gills. The gill surface area of the mako is about one-half that of a comparably sized tuna, but more than twice that of the blue shark and other nonlamnid shark species. Mako gills are also distinguished from those of other sharks by shorter diffusion distances and a more fully developed diagonal blood-flow pattern through the gill lamellae, which is similar to that found in tunas. Although the mako lacks the filament and lamellar fusions of tunas and other ram-ventilating teleosts, its gill filaments are stiffened by the elasmobranch interbranchial septum, and the lamellae appear to be stabilized by one to two vascular sacs that protrude from the lamellar surface and abut sacs of adjacent lamellae. Vasoactive agents and changes in vascular pressure potentially influence sac size, consequently effecting lamellar rigidity and both the volume and speed of water through the interlamellar channels. However, vascular sacs also occur in the blue shark, and no other structural elements of the mako gill appear specialized for ram ventilation. Rather, the basic elasmobranch gill design and pattern of branchial circulation are both conserved. Despite specializations that increase mako gill area and efficacy relative to other sharks, the basic features of the elasmobranch gill design appear to have limited selection for a larger gill surface area, and this may ultimately constrain mako aerobic performance in comparison to tunas.

Wells, R. J. D., Smith, S. E., Kohin, S., Freund, E., Spear, N., & Ramon, D. A. (2013). Age Validation of Juvenile Shortfin Mako (*Isurus oxyrinchus*) Tagged and Marked with Oxytetracycline Off Southern California. *Fishery Bulletin, 111*(2), 147-160 https://doi.org/10.7755/Fb.111.2.3

The purpose of this study was to validate aging results of juvenile Shortfin Mako (*Isurus oxyrinchus*) by vertebral band counts. Vertebrae of 29 juvenile Shortfin Mako marked with oxytetracycline (OTC) were obtained from tag-recapture activities to determine centrum growth-band deposition. Tagging occurred off southern California from 1996 to 2010, and time at liberty of the 29 sharks ranged from 4 months to 4.4 years (mean=1.3 years). Growth information also was obtained from length-frequency modal analyses (MULTIFAN and MIXDIST) by using a 29-year data set of commercial and research catch data, in addition to a tag-recapture growth model (e.g, the GROTAG model). For vertebrae samples used for age validation, shark size at time of release ranged from 79 to 142 cm fork length (FL) and from 98 to 200 cm FL at recapture. Results from band counts of vertebrae distal to OTC marks indicate 2 band pairs (2 translucent and 2 opaque) are formed each year for Shortfin Mako of the size range examined. Length-frequency analyses identified 3 age-class modes. Growth rate estimates from 26.5 to 35.5 cm/year were calculated for the first age-class mode (85 cm FL) and from 22.4 to 28.6 cm/year for the second age-class

mode (130 cm FL). Results from the tag-recapture growth model revealed fast growth during time at liberty for tagged fish of the 2 youngest age classes. Collectively, these methods suggest rapid growth of juvenile Shortfin Mako in the southern California study area and indicate biannual deposition of growth bands in vertebrae for the first 5 years.

White, W. T. (2007). Biological Observations on Lamnoid Sharks (Lamniformes) Caught by Fisheries in Eastern Indonesia. *Journal of the Marine Biological Association of the United Kingdom, 87*(3), 781-788 https://doi.org/10.1017/S0025315407056391

Fish landing site surveys in eastern Indonesia, conducted between April 2001 and March 2006, recorded seven species of lamnoid sharks (order Lamniformes) belonging to four families. Of these, Aloplidae were most abundant in the landings, with *Alopias pelagicus* contributing similar to 13% to the total biomass of all sharks recorded. Single specimens of both *Carcharias taurus* and *Odontaspis ferox* represent the first confirmed records of these two odontaspid species from Indonesian waters. The length at first maturity (L(50)) Of females and males of *Alopias pelagicus* were 2853 and 2468 min total length (TL), respectively, and size at birth was 1300-1440 mm TL. Pregnant fcmales of both A. pelagicus and A. supercillosus had litters of only two embryos (one per uterus) that were confirmed to be oophagous, but not adelphophagous. Females and males of Pseudocarcharlas kamoharal matured at 870-1030 and similar to 725 mm TL, respectively, and size at birth was 360-450 mm TL. Pregnant females contained four embryos (two per uterus) which were oophagous, but unlikely to be adelphophagous. Males of *Isurus oxyrinchus* and *I. paucus* matured at - 1860 and 20502281 turn TL, respectively. These are the first biological data reported on lamnoid sharks in Indonesian waters.

Wilmers, J., Waldron, M., & Bargmann, S. (2021). Hierarchical Microstructure of Tooth Enameloid in Two Lamniform Shark Species, *Carcharias taurus* and *Isurus oxyrinchus*. *Nanomaterials (Basel), 11*(4), 969 https://doi.org/10.3390/nano11040969

Shark tooth enameloid is a hard tissue made up of nanoscale fluorapatite crystallites arranged in a unique hierarchical pattern. This microstructural design results in a macroscopic material that is stiff, strong, and tough, despite consisting almost completely of brittle mineral. In this contribution, we characterize and compare the enameloid microstructure of two modern lamniform sharks, *Isurus oxyrinchus* (shortfin mako shark) and *Carcharias taurus* (spotted ragged-tooth shark), based on scanning electron microscopy images. The hierarchical microstructure of shark enameloid is discussed in comparison with amniote enamel. Striking similarities in the microstructures of the two hard tissues are found. Identical structural motifs have developed on different levels of the hierarchy in response to similar biomechanical requirements in enameloid and enamel. Analyzing these structural patterns allows the identification of general microstructural design principles and their biomechanical function, thus paving the way for the design of bioinspired composite materials with superior properties such as high strength combined with high fracture resistance.

Wood, A. D., Wetherbeez, B. M., Juanes, F., Kohler, N. E., & Wilga, C. (2009). Recalculated Diet and Daily Ration of the Shortfin Mako (*Isurus oxyrinchus*), with a Focus on Quantifying Predation on Bluefish (*Pomatomus saltatrix*) in the Northwest Atlantic Ocean. *Fishery Bulletin, 107*(1), 76-88 Retrieved from http://fishbull.noaa.gov/1071/wood.pdf.

The diet and daily ration of the shortfin mako (*Isurus oxyrinchus*) in the northwest Atlantic were re-examined to determine whether fluctuations in prey abundance and availability are reflected in these two biological variables. During the summers of 2001 and 2002, stomach content data were collected from fishing tournaments along the northeast coast of the United States. These data were quantified by using four diet indices and were compared to index calculations from historical diet data collected from 1972 through 1983. Bluefish (*Pomatomus saltatrix*) were the predominant prey in the 1972-83 and 2001-02 diets, accounting for 92.6% of the current diet by weight and 86.9% of the historical diet by volume. From the 2001-02 diet data, daily ration was estimated and it indicated that shortfin makos must consume roughly 4.6% of their body weight per day to fulfill energetic demands. The daily energetic requirement was broken down by using a calculated energy content for the current diet of 4909 KJ/kg. Based on the proportional energy of bluefish in the diet by weight, an average shortfin mako consumes roughly 500 kg of bluefish per year off the northeast coast of the United States. The results are discussed in relation to the potential effect of intense shortfin mako predation on bluefish abundance in the region.

Wootton, T. P., Sepulveda, C. A., & Wegner, N. C. (2015). Gill Morphometrics of the Thresher Sharks (Genus Alopias): Correlation of Gill Dimensions with Aerobic Demand and Environmental Oxygen. *Journal of Morphology, 276*(5), 589-600 https://doi.org/10.1002/jmor.20369

Gill morphometrics of the three thresher shark species (genus Alopias) were determined to examine how metabolism and habitat correlate with respiratory specialization for increased gas exchange. Thresher sharks have large gill surface areas, short water-blood barrier distances, and thin lamellae. Their large gill areas are derived from long total filament lengths and large lamellae, a morphometric configuration documented for other active elasmobranchs (i.e., lamnid sharks, Lamnidae) that augments respiratory surface area while limiting increases in branchial resistance to ventilatory flow. The bigeye thresher, *Alopias superciliosus*, which can experience prolonged exposure to hypoxia during diel vertical migrations, has the largest gill surface area documented for any elasmobranch species studied to date. The pelagic thresher shark, A. pelagicus, a warm-water epi-pelagic species, has a gill surface area comparable to that of the common thresher shark, A. vulpinus, despite the latter's expected higher aerobic requirements associated with regional endothermy. In addition, *A. vulpinus* has a significantly longer water-blood barrier distance than A. pelagicus and A. superciliosus, which likely reflects its cold, well-oxygenated habitat relative to the two other Alopias species. In fast-swimming fishes (such as *A. vulpinus* and *A. pelagicus*) cranial streamlining may impose morphological constraints on gill size. However, such constraints may be relaxed in hypoxia-dwelling species (such as *A. superciliosus*) that are likely less dependent on streamlining and can therefore accommodate larger branchial chambers and gills.

Section II: Ecology

Bedore, C. N., Hueter, R. E., & Johnsen, S. (2018). Visual Ecology of the White Shark and Shortfin Mako. *Integrative and Comparative Biology, 58*, E15-E15 Retrieved from https://sicb.burkclients.com/meetings/2018/schedule/abstractdetails.php?id=545

Visual function in the high-performance and regionally endothermic sharks is assumed to be superior to that of their ectothermic counterparts. These migratory lamnid species, including the white shark (*Carcharodon carcharias*) and the shortfin mako (*Isurus oxyrinchus*), are thought to be visually guided predators with eyes adapted to a wide range of visual habitats. Though shark vision has been of interest to researchers for several decades, most studies are limited to smaller, more accessible species. More recently, greater access to large, predatory species enables us to address outstanding questions regarding the role of vision with respect to their life history traits. To examine visual performance of the white shark and the shortfin mako, we used a visual range model developed by Nilsson et al. (2012). The input parameters included measurements of pupil diameter and focal length, photoreceptor length and peak retinal ganglion cell density, light level, and target size and contrast. Pupil diameter and focal length were measured from incidental mortalities and photographs of live specimens, whereas photoreceptor length and retinal ganglion cell data were taken from previously published data. For sharks viewing a human diver in a black wetsuit in clear, oceanic water, we calculated a visual range of approximately 20m, similar to human vision under the same conditions. However, shark vision is coarser than humans, so less detail is available to sharks for identifying objects using their visual system. Because eye size positively correlates with both sensitivity and acuity, further investigation across both species size ranges will address the functional significance of the visual system with respect to ecological patterns.

Bernal, D., Smith, D., Lopez, G., Weitz, D., Grimminger, T., Dickson, K., & Graham, J. B. (2003). Comparative Studies of High Performance Swimming in Sharks II. Metabolic Biochemistry of Locomotor and Myocardial Muscle in Endothermic and Ectothermic Sharks. *Journal of Experimental Biology, 206*(Pt 16), 2845-2857 https://doi.org/10.1242/jeb.00504

Metabolic enzyme activities in red (RM) and white (WM) myotomal muscle and in the heart ventricle (HV) were compared in two lamnid sharks (shortfin mako and salmon shark), the common thresher shark and several other actively swimming shark species. The metabolic enzymes measured were citrate synthase (CS), an index of aerobic capacity, and lactate dehydrogenase (LDH), an index of anaerobic capacity. WM creatine phosphokinase (CPK) activity, an index of rapid ATP production during burst swimming, was also quantified. Enzyme activities in RM, WM and HV were similar in the two lamnid species. Interspecific comparisons of enzyme activities at a common reference temperature (20 degrees C) show no significant differences in RM CS activity but higher CS activity in the WM and HV of the lamnid sharks compared with the other species. For the other enzymes, activities in lamnids overlapped with those of other shark species. Comparison of the HV spongy and compact myocardial layers in mako, salmon and thresher sharks reveals a significantly greater spongy CS activity in all three species but no differences in LDH activity. Adjustment of enzyme activities to in vivo RM and WM temperatures in the endothermic lamnids elevates CS and LDH in both tissues relative to the ectothermic sharks. Thus, through its enhancement of both RM and WM enzyme activity, endothermy may be an important determinant of energy supply for sustained and burst swimming in the lamnids. Although lamnid WM is differentially warmed as a result of RM endothermy, regional differences in WM CS and LDH activities and thermal sensitivities (Q(10) values) were not found. The general pattern of the endothermic

myotomal and ectothermic HV muscle metabolic enzyme activities in the endothermic lamnids relative to other active, ectothermic sharks parallels the general pattern demonstrated for the endothermic tunas relative to their ectothermic sister species. However, the activities of all enzymes measured are lower in lamnids than in tunas. Relative to lamnids, the presence of lower WM enzyme activities in the thresher shark (which is in the same order as the lamnids, has an RM morphology similar to that of the mako and salmon sharks and may be endothermic) suggests that other factors, such as behavior and swimming pattern, also affect shark myotomal organization and metabolic function.

Bernal, D., Reid, J. P., Roessig, J. M., Matsumoto, S., Sepulveda, C. A., Cech, J. J., Jr., & Graham, J. B. (2018). Temperature Effects on the Blood Oxygen Affinity in Sharks. *Fish Physiology and Biochemistry, 44*(3), 949-967 https://doi.org/10.1007/s10695-018-0484-2

In fish, regional endothermy (i.e., the capacity to significantly elevate tissue temperatures above ambient via vascular heat exchangers) in the red swimming muscles (RM) has evolved only in a few marine groups (e.g., sharks: Lamnidae, Alopiidae, and teleosts Scombridae). Within these taxa, several species have also been shown to share similar physiological adaptations to enhance oxygen delivery to the working tissues. Although the hemoglobin (Hb) of most fish has a decreased affinity for oxygen with an increase in temperature, some regionally endothermic teleosts (e.g., tunas) have evolved Hbs that have a very low or even an increased affinity for oxygen with an increase in temperature. For sharks, however, blood oxygen affinities remain largely unknown. We examined the effects of temperature on the blood oxygen affinity in two pelagic species (the regionally endothermic shortfin mako shark and the ectothermic blue shark) at 15, 20, and 25 degrees C, and two coastal ectothermic species (the leopard shark and brown smooth-hound shark) at 10, 15, and 20 degrees C. Relative to the effects of temperature on the blood oxygen affinity of ectothermic sharks (e.g., blue shark), shortfin mako shark blood was less affected by an increase in temperature, a scenario similar to that documented in some of the tunas. In the shortfin mako shark, this may act to prevent premature oxygen dissociation from Hb as the blood is warmed during its passage through vascular heat exchangers. Even though the shortfin mako shark and blue shark occupy a similar niche, the effects of temperature on blood oxygen affinity in the latter more closely resembled that of the blood in the two coastal shark species examined in this study. The only exception was a small, reverse temperature effect (an increase in blood oxygen affinity with temperature) observed during the warming of the leopard shark blood under simulated arterial conditions, a finding that is likely related to the estuarine ecology of this species. Taken together, we found species-specific differences in how temperature affects blood oxygen affinity in sharks, with some similarities between the regionally endothermic sharks and several regionally endothermic teleost fishes.

Bigman, J. S., Pardo, S. A., Prinzing, T. S., Dando, M., Wegner, N. C., & Dulvy, N. K. (2018). Ecological Lifestyles and the Scaling of Shark Gill Surface Area. *Journal of Morphology, 279*(12), 1716-1724 https://doi.org/10.1002/jmor.20879

Fish gill surface area varies across species and with respect to ecological lifestyles. The majority of previous studies only qualitatively describe gill surface area in relation to ecology and focus primarily on teleosts. Here, we quantitatively examined the relationship of gill surface area with respect to specific ecological lifestyle traits in elasmobranchs, which offer an independent evaluation of observed patterns in teleosts. As gill surface area increases ontogenetically with body mass, examination of how gill surface area varies with ecological lifestyle traits must be assessed in the context of its allometry (scaling). Thus,

we examined how the relationship of gill surface area and body mass across 11 shark species from the literature and one species for which we made measurements, the Gray Smoothhound *Mustelus californicus*, varied with three ecological lifestyle traits: activity level, habitat, and maximum body size. Relative gill surface area (gill surface area at a specified body mass; here we used 5,000g, termed the 'standardized intercept') ranged from 4,724.98 to 35,694.39 cm(2) (mean and standard error: 17,796.65 +/- 2,948.61 cm(2)) and varied across species and the ecological lifestyle traits examined. Specifically, larger-bodied, active, oceanic species had greater relative gill surface area than smaller-bodied, less active, coastal species. In contrast, the rate at which gill surface area scaled with body mass (slope) was generally consistent across species (0.85 +/- 0.02) and did not differ statistically with activity level, habitat, or maximum body size. Our results suggest that ecology may influence relative gill surface area, rather than the rate at which gill surface area scales with body mass. Future comparisons of gill surface area and ecological lifestyle traits using the quantitative techniques applied in this study can provide further insight into patterns dictating the relationship between gill surface area, metabolism, and ecological lifestyle traits.

Biton-Porsmoguer, S., Banaru, D., Boudouresque, C. F., Dekeyser, I., Bearez, P., & Miguez-Lozano, R. (2017). Compared Diet of Two Pelagic Shark Species in the Northeastern Atlantic Ocean. *Vie Et Milieu-Life and Environment, 67*(1), 21-25 Retrieved from https://tel.archives-ouvertes.fr/MIO/hal-01833598

The diet of shortfin makos (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*) were studied by analyzing stomach contents of specimens captured by longliners near the Azores Archipelago and between the Azores and the Iberian Peninsula. The diet of the shortfin mako is strongly dominated by teleosts (mainly *Scomberesox saurus*), while that of the blue shark is strongly dominated by cephalopods (mainly *Histioteuthis sp*.). In mass of non-reconstituted prey, sea mammals play an important role, especially for the blue shark.

Biton Porsmoguer, S., Banaru, D., Bearez, P., Dekeyser, I., Merchan Fornelino, M., & Boudouresque, C. F. (2014). Unexpected Headless and Tailless Fish in the Stomach Content of Shortfin Mako *Isurus oxyrinchus*. *PLOS ONE, 9*(2), e88488 https://doi.org/10.1371/journal.pone.0088488

The stomach content of 113 individuals of shortfin mako *Isurus oxyrinchus* was analyzed. Individuals were sampled at landing in Vigo (Spain) and captured by sea-surface long-liners in the vicinity of the Azores Archipelago and between Azores and the Iberian Peninsula, in March and October 2012, and March 2013. Teleosts constituted the dominant item, mainly Atlantic saury Scomberesox saurus (87% of teleost prey). Among them, 94% were deprived of both head and the caudal fin, while the flesh and bones of the body were preserved. The presence of eye's lenses, the number of which was consistent with the number of fish remains, likely rules out the elimination of the heads before ingestion. There is no obvious explanation for this unexpected and unrecorded pattern of digestion.

Bizzarro, J. J., Carlisle, A. B., Smith, W. D., & Cortés, E. (2017). Chapter Four - Diet Composition and Trophic Ecology of Northeast Pacific Ocean Sharks. In *Advances in Marine Biology.* S. E. Larson & D. Lowry (Eds.), (Vol. 77, pp. 111-148): Academic Press https://doi.org/10.1016/bs.amb.2017.06.001

Although there is a general perception of sharks as large pelagic, apex predators, most sharks are smaller, meso- and upper-trophic level predators that are associated with the seafloor. Among 73 shark species documented in the eastern North Pacific (ENP), less than half reach maximum lengths >200cm, and 78% occur in demersal or benthic regions of the continental shelf or slope. Most small (≤200cm) species (e.g., houndsharks) and demersal, nearshore juveniles of larger species (e.g., requiem sharks) consume small teleosts and decapod crustaceans, whereas large species in pelagic coastal and oceanic environments feed on large teleosts and squids. Several large, pelagic apex predator species occur in the ENP, but the largest species (i.e., Basking Shark, Whale Shark) consume zooplankton or small nekton. Size-based dietary variability is substantial for many species, and segregation of juvenile and adult foraging habitats also is common (e.g., Horn Shark, Shortfin Mako). Temporal dietary differences are most pronounced for temperate, nearshore species with wide size ranges, and least pronounced for smaller species in extreme latitudes and deep-water regions. Sympatric sharks often occupy various trophic positions, with resource overlap differing by space and time and some sharks serving as prey to other species. Most coastal species remain in the same general region over time and feed opportunistically on variable prey inputs (e.g., season migrations, spawning, or recruitment events), whereas pelagic, oceanic species actively seek hot spots of prey abundance that are spatiotemporally variable. The influence of sharks on ecosystem structure and regulation has been downplayed compared to that of large teleosts species with higher per capita consumption rates (e.g., tunas, billfishes). However, sharks also exert indirect influences on prey populations by causing behavioural changes that may result in restricted ranges and reduced fitness. Except for food web modelling efforts in Alaskan waters, the trophic impacts of sharks are poorly incorporated into current ecosystem approaches to fisheries management in the NEP.

Blaber, S. J. M., Dichmont, C. M., White, W., Buckworth, R., Sadiyah, L., Iskandar, B., . . . Fahmi. (2009). Elasmobranchs in Southern Indonesian Fisheries: The Fisheries, the Status of the Stocks and Management Options. *Reviews in Fish Biology and Fisheries, 19*(3), 367-391 https://doi.org/10.1007/s11160-009-9110-9

The biology of elasmobranchs makes them very vulnerable to fishing pressure and there is increasing international concern over their exploitation. In northern Australia the stocks of some species may be shared with those in southern Indonesia. Indonesia has the highest landings of elasmobranchs worldwide (> 100,000 t p.a.) and millions of Indonesian artisanal fishers rely heavily on elasmobranchs taken in target fisheries. They are also taken by industrial trawlers and as bycatch in pelagic tuna fisheries. This paper, resulting from a collaborative project between Australia and Indonesia, summarises the elasmobranch fisheries; the characteristics of the fisheries are outlined, the status of the stocks are assessed, and management options described and discussed. The project focussed on representative markets and fish landing sites in southern Indonesia from 2001 to 2005. Data were from market surveys, the records of the Indonesian Directorate General of Capture Fisheries, and from research cruises. Data from the ongoing tuna monitoring programme showed that shark bycatch from the tuna fleets forms about 11% of shark landings in Indonesia. Yield per recruit and related analyses were used to integrate biological information to indicate the productivity of each species to allow for management policy options and constraints. Research cruise data show that catch rates of elasmobranchs in the Java Sea declined by at least one order of magnitude between 1976 and 1997. The results indicate strongly that many of the shark and ray species in Indonesia are overfished and that the most effective management strategy may need to involve capacity control, such as licencing, gear restrictions and catch limits, together with controls on the fin trade.

Brodie, S., Jacox, M. G., Bograd, S. J., Welch, H., Dewar, H., Scales, K. L., . . . Hazen, E. L. (2018). Integrating Dynamic Subsurface Habitat Metrics into Species Distribution Models. *Frontiers in Marine Science, 5* https://doi.org/10.3389/fmars.2018.00219

Species distribution models (SDMs) have become key tools for describing and predicting species habitats. In the marine domain, environmental data used in modeling species distributions are often remotely sensed, and as such have limited capacity for interpreting the vertical structure of the water column, or are sampled in situ, offering minimal spatial and temporal coverage. Advances in ocean models have improved our capacity to explore subsurface ocean features, yet there has been limited integration of such features in SDMs. Using output from a data-assimilative configuration of the Regional Ocean Modeling System, we examine the effect of including dynamic subsurface variables in SDMs to describe the habitats of four pelagic predators in the California Current System (swordfish *Xiphias gladius*, blue sharks *Prionace glauca*, common thresher sharks *Alopias vulpinus*, and shortfin mako sharks lsurus oxyrinchus). Species data were obtained from the California Drift Gillnet observer program (1997-2017). We used boosted regression trees to explore the incremental improvement enabled by dynamic subsurface variables that quantify the structure and stability of the water column: isothermal layer depth and bulk buoyancy frequency. The inclusion of these dynamic subsurface variables significantly improved model explanatory power for most species. Model predictive performance also significantly improved, but only for species that had strong affiliations with dynamic variables (swordfish and shortfin mako sharks) rather than static variables (blue sharks and common thresher sharks). Geospatial predictions for all species showed the integration of isothermal layer depth and bulk buoyancy frequency contributed value at the mesoscale level (< 100 km) and varied spatially throughout the study domain. These results highlight the utility of including dynamic subsurface variables in SDM development and support the continuing ecological use of biophysical output from ocean circulation models.

Byrne, M. E., Vaudo, J. J., Harvey, G. C. M., Johnston, M. W., Wetherbee, B. M., & Shivji, M. (2019). Behavioral Response of a Mobile Marine Predator to Environmental Variables Differs across Ecoregions. *Ecography, 42*(9), 1569-1578 https://doi.org/10.1111/ecog.04463

Animal movement and habitat selection are in part a response to landscape heterogeneity. Many studies of movement and habitat selection necessarily use environmental covariates that are readily available over large-scales, which are assumed representative of functional habitat features such as resource availability. For widely distributed species, response to such covariates may not be consistent across ecosystems, as response to any specific covariate is driven by its biological relevance within the context of each ecosystem. Thus, the study of any widely distributed species within a limited geographic region may provide inferences that are not widely generalizable. Our goal was to evaluate the response of a marine predator to a suite of environmental covariates across a wide ecological gradient. We identified two behavioral states (resident and transient) in the movements of shortfin mako sharks *Isurus oxyrinchus* tracked via satellite telemetry in two regions of the western North Atlantic Ocean: the tropical Caribbean/Gulf of Mexico marginal sea (CGM), and the temperate waters of the open western Atlantic Ocean (OWA). We compared patterns of resident behavior between regions, and modeled relationships between oceanographic variables and resident behavior. We tracked 39 sharks during 2013-2015. Resident behavior was associated with shallow, continental shelf and slope waters in both regions. In the OWA resident behavior was associated with low sea surface temperature and high primary productivity, however, sharks exhibited no response to either variable in the CGM. There was a

negative relationship between sea-surface height gradient (a proxy for oceanic fronts) and resident behavior in the OWA, and a positive relationship in the CGM. Our observations likely reflect shark responses to regional variability in factors responsible for the distribution and availability of prey. Our study illustrates the importance of studying widely distributed species in a consistent manner over large spatial scales.

Cordova-Zavaleta, F., Mendo, J., Briones-Hernandez, S. A., Acuna-Perales, N., Gonzalez-Pestana, A., Alfaro-Shigueto, J., & Mangel, J. C. (2018). Food Habits of the Blue Shark, *Prionace glauca* (Linnaeus, 1758), in Waters Off Northern Peru. *Fishery Bulletin, 116*(3-4), 310-322 https://doi.org/10.7755/Fb.116.3-4.9

The blue shark (*Prionace glauca*) is the most landed shark species in Peruvian shark fisheries, representing 42% of total landings. Despite its importance for fisheries, the ecological role of the blue shark in Peruvian waters remains poorly understood. Therefore, in this study, we aimed to assess the food habits of blue sharks off northern Peru through stomach content analysis. Between February and December of 2015, 143 stomachs were collected and 28 found to be were empty. Individuals measured from 110.0 to 299.4 cm in total length. The results indicate that blue sharks have epipelagic and mesobathypelagic feeding habits, preying upon a wide number of prey taxa (42 species) but with a diet dominated by cephalopods, especially Argonauta spp. and Ancistrocheirus lesueurii. Diets differed by size class and location, suggesting that longitudinal movements are related to increments in body size. In addition, we propose that blue sharks scavenge for food on the basis of finding the cyprid larval stage and juvenile cosmopolitan duck barnacle (Lepas anatifera) associated with the prey item 'unidentified cephalopods.' The present study contributes new information on the diet of blue sharks.

Cortes, E., Arocha, F., Beerkircher, L., Carvalho, F., Domingo, A., Heupel, M., . . . Simpfendorfer, C. (2010). Ecological Risk Assessment of Pelagic Sharks Caught in Atlantic Pelagic Longline Fisheries. *Aquatic Living Resources, 23*(1), 25-34 https://doi.org/10.1051/alr/2009044

An ecological risk assessment (ERA; also known as productivity and susceptibility analysis, PSA) was conducted on eleven species of pelagic elasmobranchs (10 sharks and 1 ray) to assess their vulnerability to pelagic longline fisheries in the Atlantic Ocean. This was a level-3 quantitative assessment consisting of a risk analysis to evaluate the biological productivity of these species and a susceptibility analysis to assess their propensity to capture and mortality in pelagic longline fisheries. The risk analysis estimated productivity (intrinsic rate of increase, r) using a stochastic Leslie matrix approach that incorporated uncertainty in age at maturity, lifespan, age-specific natural mortality and fecundity. Susceptibility to the fishery was calculated as the product of four components, which were also calculated quantitatively: availability of the species to the fleet, encounterability of the gear given the species vertical distribution, gear selectivity and post-capture mortality. Information from observer programs by several ICCAT nations was used to derive fleet-specific susceptibility values. Results indicated that most species of pelagic sharks have low productivities and varying levels of susceptibility to pelagic longline gear. A number of species were grouped near the high-risk area of the productivity-susceptibility plot, particularly the silky (*Carcharhinus falciformis*), shortfin mako (*Isurus oxyrinchus*), and bigeye thresher (*Alopias superciliosus*) sharks. Other species, such as the oceanic whitetip (*Carcharhinus longimanus*) and longfin mako (*Isurus paucus*) sharks, are also highly vulnerable. The blue shark (*Prionace glauca*) has intermediate vulnerability, whereas the smooth hammerhead (*Sphyrna zygaena*), scalloped hammerhead (*Sphyrna lewini*), and porbeagle (*Lamna nasus*) sharks are less vulnerable, and the pelagic

stingray (*Pteroplatytrygon violacea*) and common thresher (*Alopias vulpinus*) sharks have the lowest vulnerabilities. As a group, pelagic sharks are particularly vulnerable to pelagic longline fisheries mostly as a result of their limited productivity.

Cosgrove, R., Arregui, I., Arrizabalaga, H., Goni, N., & Neilson, J. D. (2015). Predation of Pop-up Satellite Archival Tagged Albacore (Thunnus Alalunga). *Fisheries Research, 162*, 48-52 https://doi.org/10.1016/j.fishres.2014.09.003

Three out of eight albacore (*Thunnus alalunga*) tagged with pop-up satellite archival tags (PSATs) in the greater Bay of Biscay area of the North East Atlantic were predated as indicated by missing light level data, sudden increases in temperature, and substantial changes in depth profiles. Recorded stomach temperatures and differences between stomach and ambient water temperatures were consistent with shortfin maim (*Isurus oxyrinchus*) and porbeagle (*Lamna nasus*) sharks. Vertical behavior in the form of diel migrations, deep dives and extensive periods spent close to the surface during day and night time was again consistent with Lamnid sharks. The observed predation rate was considered to be elevated due to irregular post-release behavior as opposed to symptomatic of natural mortality.

Estrada, J. A., Rice, A. N., Lutcavage, M. E., & Skomall, G. B. (2003). Predicting Trophic Position in Sharks of the North-West Atlantic Ocean Using Stable Isotope Analysis. *Journal of the Marine Biological Association of the United Kingdom, 83*(6), 1347-1350 https://doi.org/10.1017/S0025315403008798

Trophic positions (TP) were estimated for the blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), thresher shark (*Alopias vulpinus*), and basking shark (*Celorhinus maximus*) using stable isotope ratios of carbon (delta(13)C) and nitrogen (delta(15)N). The basking shark had the lowest TP (3.1) and delta(15)N value (10.4 parts per thousand), whereas the thresher shark had the highest values (4.5, 15.2parts per thousand). Mako sharks showed considerable variation in TP and isotopic values, possibly due to foraging from both inshore and offshore waters. Thresher sharks were significantly more enriched in delta(15)N than blue sharks and mako sharks, suggesting a different prey base. The delta(13)C values of thresher sharks and mako sharks varied significantly, but neither was significantly different from that of blue sharks. No statistical differences were found between our TP estimations and those derived from published stomach contents analyses, indicating that stable isotope data may be used to estimate the trophic status of sharks.

Furlong-Estrada, E., Tovar-Avila, J., & Rios-Jara, E. (2014). Ecological Risk Assessment of Artisanal Capture Methods on Sharks Fished at the Entrance of the Gulf of California. *Hidrobiologica, 24*(2), 83-97 Retrieved from http://www.scielo.org.mx/scielo.php?pid=S0188-88972014000200001&script=sci_abstract&tlng=en

In Mexico sharks are an important fishery resource, however, their biological characteristics make them highly vulnerable to overfishing. In order to assess the vulnerability (v) and ecological risk (ER) of 20 species caught by the artisanal fishery at the entrance of the Gulf of California, a Productivity and Susceptibility Analysis (PSA) was performed taking into consideration the main fishing capture systems used in this region (gillnets and longlines). The results showed that thirteen species (65%) have medium biological productivity and the rest of them (35%) have low. The catch susceptibility was low to the total

species analyzed. The ER estimated was high for seven species and medium for 13 of them. Likewise, all species were located in the medium category of vulnerability. The productivity values obtained for the species are comparable to those reported in similar research and confirm the considerable sensitivity of sharks to overfishing. Moreover the low susceptibility of capture in all species is related to the limited autonomy of the artisanal boats and and their operation range. The PSA is a rapid method applicable to fisheries that have insufficient information for traditional fisheries assessments and its application in other elasmobranch fisheries can help to delineate and prioritize fisheries management policies and research.

Gorni, G. R., Loibel, S., Goitein, R., & Amorim, A. F. (2012). Stomach Contents Analysis of Shortfin Mako (*Isurus oxyrinchus*) Caught Off Southern Brazil: A Bayesian Analysis. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 68*(5), 1933-1937 Retrieved from http://www.iccat.int/Documents/CVSP/CV068_2012/no_5/CV0680501933.pdf

This study proposes to ascertain the importance of each alimentary category in the *Isurus oxyrinchus* diet composition, as well, to reinforce the use of the Bayesian approach for analysis of these data. Shortfin mako were collected during fishing cruises carried out by the longline fleet of Santos and Guaruja, Sao Paulo State, from July 2007 to June 2008. The collection of the stomachs was done on board during evisceration. The stomach contents have been identified to the smallest possible taxa. For Bayesian model formulation, each alimentary item was clustered in four food categories previously defined as: teleost fishes, cephalopod molluscs, crustaceans, and others. After the stomach contents analysis 144 food items were identified, which belonged to 11 taxa. Following the calculation, the most important food category of *I. oxyrinchus* is comprised of teleost fishes (PM=0.68), followed by cephalopod molluscs (PM = 0.12). Crustaceans and other items were responsible for the posterior mode less than 0.1, indicating low importance in the shortfin mako diet. The Bayesian approach should be useful to analyse the diet of great top predators, which are usually caught in small numbers.

Hammerschlag, N., Gallagher, A. J., & Carlson, J. K. (2013). A Revised Estimate of Daily Ration in the Tiger Shark with Implication for Assessing Ecosystem Impacts of Apex Predators. *Functional Ecology, 27*(5), 1273-1274 https://doi.org/10.1111/1365-2435.12157

No abstract.

Harford, W. J. (2013). Trophic Modeling of Shortfin Mako (*Isurus oxyrinchus*) and Bluefish (Pomatomus Saltatrix) Interactions in the Western North Atlantic Ocean. *Bulletin of Marine Science, 89*(1), 161-188 https://doi.org/10.5343/bms.2011.1150

An ecosystem model of the western North Atlantic Ocean was constructed that emphasized predator-prey dynamics of shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, and bluefish, Pomatomus saltatrix (Linnaeus, 1766). Modeling served to synthesize knowledge about food consumption rates and feeding habits into a framework that could be used to characterize uncertainty in the dynamics of key trophic linkages. The model was used to investigate whether directed fishing for each member of this predator-prey linkage could result in indirect effects on (1) shortfin mako biomass and yield as a result of changes in shared bluefish resources or (2) bluefish biomass and yield as a result of changes in shortfin mako

biomass. A preliminary exploration of fishing policies suggested competition between shortfin mako and bluefish fisheries for shared bluefish resources, as increased catches of bluefish had deleterious effects on shortfin mako biomass and yield. Conversely, bluefish biomass and yield were relatively invariant to catch-driven changes in shortfin mako biomass. Sensitivity analysis indicated consistency in model outcomes across a variety of model configurations, but outcomes were sensitive to the magnitude of bluefish consumption by shortfin mako. Model outcomes formed the basis for discussing additional knowledge gaps and alternative modeling assumptions and for guiding research aimed at broadening our understanding of trophic interrelationships involving shortfin mako and bluefish.

Henderson, A. C., Quigley, D. T. G., & Flannery, K. (1999). The Shortfin Mako Shark *Isurus oxyrinchus* Rafinesque, and the Pelagic Stingray Dasyatis Violacea Bonaparte, in Irish Waters. *The Irish Naturalists' Journal, 26*(7/8), 260-266 Retrieved from http://www.jstor.org/stable/25536276

The third confirmed record of the shortfin mako shark and the first records of the pelagic stingray in Irish waters are presented. Morphometric measurements were collected for both species, and a parasitic investigation yielded two species of copepod new to Irish waters.

Holland, K. N., Wetherbee, B. M., Lowe, C. G., & Meyer, C. G. (1999). Movements of Tiger Sharks (Galeocerdo Cuvier) in Coastal Hawaiian Waters. *Marine Biology, 134*(4), 665-673 https://doi.org/10.1007/s002270050582

Externally and internally implanted sonic transmitters were used to track the movements of eight tiger sharks (Galeocerdo cuvier) ranging between 200 and 417 cm total length (TL), captured by hook-and-line on the south coast of Oahu, Hawaii, between 1993 and 1997. Attachment of the transmitters was facilitated by the fact that captured sharks exhibited tonic immobility when restrained and inverted at the side of the tagging vessel. Three common themes emerged from the horizontal movements of the tracked sharks: (1) offshore movements away from the island, (2) extended periods of directed, "straight-line" swimming, (3) orientation to the Penguin Banks - a shallow bank located similar or equal to 35 km from the release point. In shallow water (<300 m) the sharks swam predominantly close to the bottom, in open water (>300 m)they swam within the mixed layer at depths of similar to 80 m. One shark dove briefly to 335 m. The average estimated swimming speed of sharks traversing open water was 0.29 body length (BL) s(-1). Two sharks were recaptured after termination of the tracks; one of these sharks was recaptured twice, with a total time at liberty of 377 d. The data suggest that Hawaiian tiger sharks move within large home ranges and that they can efficiently navigate between distant parts of their range, even when this requires crossing open ocean waters.

Howey, L. A., Wetherbee, B. M., Wood, A., & Shivji, M. S. (2009, July 22-27, 2009). *Comparative Habitat Utilization of the Blue Shark (Prionace glauca) and Shortfin Mako (Isurus oxyrinchus).* Paper presented at the American Elasmobranch Society 25th Annual Meeting, Portland, OR. Retrieved from https://nsuworks.nova.edu/occ_facpresentations/125

Species common in western North Atlantic continental shelf waters during summer months. Both undergo seasonal migrations to warmer or southern locations. Mako sharks are regional endotherms that maintain elevated temperatures in specific body parts, whereas blue sharks are typical ectotherms. Despite striking physiological and morphological differences between these species, they utilize roughly

the same habitat on the continental shelf. To compare fine-scale habitat use of these two species we used pop-up satellite tags which archive depth, temperature, and light to examine environmental utilization of blue (n=10) and shortfin mako (n=6) sharks during migrations away from the shelf. All blue shark and two shortfin mako displayed long-distance migrations. Both blue and mako sharks occupied water of similar depth and temperature on the shelf, despite different prey preferences. During migration, mean depth of blue sharks was 85m compared to 50m for mako sharks. Both blue and shortfin mako sharks utilized 16-22 °C waters for 75% and 60% of their time, respectively. Both species dove frequently during migration with maximum recorded depths of 855m for a blue shark and 866m for a mako. The greatest straight-line distance traveled by a blue shark was 2485km (Cape Cod to Puerto Rico) and 2100km for a mako (Cape Cod to the Bahamas). Differences between these species while on the continental shelf appear to reflect prey consumption rather than habitat utilization; whereas, during migration the two species exhibited more pronounced differences in habitat utilization.

Howey, L. A., Tolentino, E. R., Papastamatiou, Y. P., Brooks, E. J., Abercrombie, D. L., Watanabe, Y. Y., . . . Jordan, L. K. (2016). Into the Deep: The Functionality of Mesopelagic Excursions by an Oceanic Apex Predator. *Ecology & Evolution, 6*(15), 5290-5304 https://doi.org/10.1002/ece3.2260

Comprehension of ecological processes in marine animals requires information regarding dynamic vertical habitat use. While many pelagic predators primarily associate with epipelagic waters, some species routinely dive beyond the deep scattering layer. Actuation for exploiting these aphotic habitats remains largely unknown. Recent telemetry data from oceanic whitetip sharks (*Carcharhinus longimanus*) in the Atlantic show a strong association with warm waters (>20 degrees C) less than 200 m. Yet, individuals regularly exhibit excursions into the meso- and bathypelagic zone. In order to examine deep-diving behavior in oceanic whitetip sharks, we physically recovered 16 pop-up satellite archival tags and analyzed the high-resolution depth and temperature data. Diving behavior was evaluated in the context of plausible functional behavior hypotheses including interactive behaviors, energy conservation, thermoregulation, navigation, and foraging. Mesopelagic excursions (n = 610) occurred throughout the entire migratory circuit in all individuals, with no indication of site specificity. Six depth-versus-time descent and ascent profiles were identified. Descent profile shapes showed little association with examined environmental variables. Contrastingly, ascent profile shapes were related to environmental factors and appear to represent unique behavioral responses to abiotic conditions present at the dive apex. However, environmental conditions may not be the sole factors influencing ascents, as ascent mode may be linked to intentional behaviors. While dive functionality remains unconfirmed, our study suggests that mesopelagic excursions relate to active foraging behavior or navigation. Dive timing, prey constituents, and dive shape support foraging as the most viable hypothesis for mesopelagic excursions, indicating that the oceanic whitetip shark may regularly survey extreme environments (deep depths, low temperatures) as a foraging strategy. At the apex of these deep-water excursions, sharks exhibit a variable behavioral response, perhaps, indicating the presence or absence of prey.

Klarian, S. A., Cornejo, A., Sallaberry-Pincheira, P., Barria, P., & Melendez, R. (2016). Assessing the Trophic Position of Two Sharks from the Open Waters of the Southeastern Pacific Ocean. *Latin American Journal of Aquatic Research, 44*(2), 429-432 https://doi.org/10.3856/vol44-issue2-fulltext-25

Stable isotope analyses for shortfin mako (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*) were conducted to assess their trophic position in two periods of time (before 1980 and after 2000) in the Southeastern Pacific waters (SEP). Both sharks showed that their trophic position decreased over time ($P < 0.05$). Many factors could be involved in this change such as dietary shifts, prey availability, or indirect fishing effects in SEP waters.

Klarian, S. A., Canales-Cerro, C., Barria, P., Zarate, P., Concha, F., Hernandez, S., . . . Melendez, R. (2018). New Insights on the Trophic Ecology of Blue (*Prionace glauca*) and Shortfin Mako Sharks (*Isurus oxyrinchus*) from the Oceanic Eastern South Pacific. *Marine Biology Research, 14*(2), 173-182 https://doi.org/10.1080/17451000.2017.1396344

The blue shark (*Prionace glauca*) and the shortfin mako shark (*Isurus oxyrinchus*) are two large and highly migratory sharks distributed in most oceans. Although they are often caught in the south Pacific Ocean long-line fisheries, their trophic ecology is poorly understood. Stable isotopes with Bayesian mixing and dependence concentration models were performed to determine the diet and trophic differences between the two species in the South-eastern Pacific Ocean. According to the mixing models, fishes are the most important prey of these sharks. Dolphin calves and remains were found in the stomachs of both species, which represents a novel finding in trophic ecology of South Pacific sharks. Intra-specific differences were found in P. glauca, but not in specimens of *I. oxyrinchus*. The two sharks showed a high degree of diet overlap (73%), primarily over mackerel and dolphin carcasses. Our results indicate that blue and shortfin mako sharks have a generalist feeding strategy in the eastern Pacific Ocean, with a strong preference for teleost fishes and also for dolphin carcasses. Therefore, trophic studies are useful to understand energy flow through the food web, and the trophic position of key species.

Li, Y. K., Zhang, Y. Y., & Dai, X. J. (2016). Trophic Interactions among Pelagic Sharks and Large Predatory Teleosts in the Northeast Central Pacific. *Journal of Experimental Marine Biology and Ecology, 483*, 97-103 https://doi.org/10.1016/j.jembe.2016.04.013

Sharks are considered to play important roles in structuring marine ecosystems, consequently understanding their trophic ecology and interactions with other marine predators is required. In the central Pacific Ocean, whether the trophic roles of pelagic sharks are complementary or redundant to large teleost predators remains unclear. In this study, stable carbon and nitrogen isotope analysis were used to examine the isotopic niche overlap of eight pelagic shark species and six pelagic teleost predators, including tuna and billfish. Large intra-specific variation and minimal inter-specific variation in both delta N-15 and delta C-13 values were observed among sharks and teleosts. Moreover, there was a high degree of trophic overlap among pelagic shark and teleost species, with the exception of the blue shark, the delta C-13 values of which indicated a much longer foraging time in the purely pelagic waters. Moreover, although the stable isotopic data suggested that the pelagic sharks in the study area share similar prey and habitats with other pelagic predators, such as tuna and billfish, blue sharks and shortfin mako sharks did not show isotopic overlap with these predators. These data highlight the diverse roles among pelagic sharks, supporting previous findings that this species complex is not trophically redundant; but further studies on the diet and fine-scale habitat used are required to verify this hypothesis.

Li, Y. K., Gao, X. D., Wang, L. Y., & Fang, L. (2018). [Trophic Niche Partitioning of Pelagic Sharks in Central Eastern Pacific Inferred from Stable Isotope Analysis.]. *Ying Yong Sheng Tai Xue Bao, 29*(1), 309-313 https://doi.org/10.13287/j.1001-9332.201801.037

As the apex predators of the open ocean ecosystems, pelagic sharks play important roles in stabilizing the marine food web through top-down control. Stable isotope analysis is a powerful tool to investigate the feeding ecology. The carbon and nitrogen isotope ratios can be used to trace food source and evaluate the trophic position of marine organisms. In this study, the isotope values of 130 pelagic sharks from 8 species in Central Eastern Pacific were analyzed and their trophic position and niche were calculated to compare the intra/inter-specific resource partitioning in the Central Eastern Pacific ecosystem. The results exhibited significant differences in both carbon and nitrogen isotope values among the shark species. The trophic levels ranged from 4.3 to 5.4 in the Central Eastern Pacific shark community. The trophic niche of blue sharks and shortfin mako sharks showed no overlap with the other shark species, exhibiting unique ecological roles in the open ocean food web. These data highlighted the diverse roles among pelagic sharks, supporting previous findings that this species is not trophically redundant and the trophic niche of pelagic sharks can not be simply replaced by those of other top predator species.

Loefer, J. K., Sedberry, G. R., & McGovern, J. C. (2005). Vertical Movements of a Shortfin Mako in the Western North Atlantic as Determined by Pop-up Satellite Tagging. *Southeastern Naturalist, 4*(2), 237-246 https://doi.org/10.1656/1528-7092(2005)004[0237:Vmoasm]2.0.Co;2

A self-releasing satellite "pop-up" tag was attached to an adult male shortfin mako captured off of the southeastern United States. The tag was deployed in the spring of 2002 and detached after 60 days in an area approximately 72 km from the tagging location. Archived tag data indicated a depth range of 0 to 556 m in ambient temperatures between 10.4 and 28.6 degrees C. The shortfin mako demonstrated a diel pattern of vertical movement defined by greater mean depths and larger depth ranges during daylight hours. Depth and temperature data suggested a seasonal behavioral change in vertical movements associated with an increase in sea-surface temperatures during the study period.

Lopez, S., Melendez, R., & Barria, P. (2009). Feeding of the Shortfin Mako Shark *Isurus oxyrinchus* Rafinesque, 1810 (Lamniformes: Lamnidae) in the Southeastern Pacific. *Revista De Biologia Marina Y Oceanografia, 44*(2), 439-451 https://doi.org/10.4067/S0718-19572009000200017

In order to examine the feeding of mako shark *Isurus oxyrinchus*, the stomach content of 205 specimens, captured between 21 degrees and 35 degrees S and 78 degrees and 118 degrees W off Chile, during 2005 and 2006 were analyzed. The 47.8% of the sharks had food in their stomachs. The numeric, frequency and weight methods and the index of relative importance (IIR) were used to describe their diet. The diet was compared between sexes and spatio-temporal variations of the diet were also determined. The diet of the mako shark consisted of 17 prey items. Teleost fishes were the most important prey item (86.9% IIR), followed by cephalopods (12.3% IIR). Other preys were in low frequency (<1% IIR) and they were represented by elasmobranch fishes, marine birds and marine mammals. No differences in diet were found between sexes of shortfin mako, however, it was detected variation between seasons and fishing zones. According to its diet the mako shark is considered a generalist species.

Lyons, K., Kacev, D., Preti, A., Gillett, D., Dewar, H., & Kohin, S. (2019). Species-Specific Characteristics Influence Contaminant Accumulation Trajectories and Signatures across Ontogeny in Three Pelagic Shark Species. *Environmental Science & Technology, 53*(12), 6997-7006 https://doi.org/10.1021/acs.est.8b07355

Factors influencing organic contaminant accumulation in sharks, especially across ontogeny, are not well-known. Contaminant concentrations were measured in three species of sharks (Blue, Shortfin Mako, and Common Thresher) across a range of size classes (neonatal to adult) that vary in their ecological and physiological characteristics. Empirical data was compared to a theoretical framework that predicted the shape of lifetime accumulation curves. We found that a one-size-fits-all accumulation model was not appropriate as species-specific characteristics had a significant effect on contaminant accumulation trajectories. Maternal offloading likely has an important effect on determining neonatal shark contaminant starting points, and trophic ecology and physiology may interact to affect the shape of species' contaminant accumulation curves. Makos were found to have the highest accumulation potential and Blues the lowest, with Threshers being intermediate in accumulation potential. Changes in species' ecology and/or physiology were also reflected in contaminant signature changes over ontogeny. If contaminant concentrations are to be used as a proxy for risk, species-specific characteristics need to be taken into account when estimating contaminant exposure and its potential negative effects on shark health and human consumption safety.

Lyons, K., Preti, A., Madigan, D. J., Wells, R. J., Blasius, M. E., Snodgrass, O. E., . . . Lowe, C. G. (2015). Insights into the Life History and Ecology of a Large Shortfin Mako Shark *Isurus oxyrinchus* Captured in Southern California. *Journal of Fish Biology, 87*(1), 200-211 https://doi.org/10.1111/jfb.12709

In June 2013, a record-breaking female *Isurus oxyrinchus* (total length 373 cm, mass 600 kg) was captured by rod and reel off Huntington Beach, California, where it was subsequently donated to research and provided a rare opportunity to collect the first data for a female *I. oxyrinchus* of this size. Counts of vertebral band pairs estimate the shark to have been c. 22 years old, depending upon assumptions of band-pair deposition rates, and the distended uteri and spent ovaries indicated that this shark had recently given birth. The stomach contained a c. 4 year-old female California sea lion Zalophus californianus that confirmed the high trophic position of this large *I. oxyrinchus*, which was corroborated with the high levels of measured contaminants and tissue isotope analyses.

MacNeill, M. A., Skomal, G. B., & Fisk, A. T. (2005). Stable Isotopes from Multiple Tissues Reveal Diet Switching in Sharks. *Marine Ecology Progress Series, 302*, 199-206 https://doi.org/10.3354/meps302199

Food web relationships in marine systems have traditionally been defined through stomach content analysis, but biochemical techniques have recently emerged to validate and broaden temporal diet patterns. Stable isotope analysis has become a practical tool for evaluating these relationships in aquatic systems; however, routine sampling of muscle tissue captures only part of the trophic information available from each animal. We compared delta N-15 and delta C-13 values among liver, muscle and cartilage in the blue shark *Prionace glauca*, shortfin mako *Isurus oxyrinchus*, and common thresher *Alopias vulpinus* from the northwest Atlantic to show how multiple-tissue sampling captured feeding

relationships which would have been invisible to muscle tissue alone. Specifically, we demonstrated evidence of a cephalopod to bluefish Pomatomus saltatrix diet switch in the shortfin mako in spring, and found that the blue shark and common thresher have consistent diets throughout the year. We concluded that consistency observed among stable isotope values in multiple tissues implied that the fish were in steady-state with the isotope ratios of their diet and that multiple tissues should be used in trophic assessments of large pelagic fishes. Further experiments to quantify the turnover of stable isotopes in different tissues and species are needed to improve the accuracy of stable-isotope analyses.

Maia, A., Queiroz, N., Correia, J. P., & Cabral, H. (2006). Food Habits of the Shortfin Mako, *Isurus oxyrinchus*, Off the Southwest Coast of Portugal. *Environmental Biology of Fishes, 77*(2), 157-167 https://doi.org/10.1007/s10641-006-9067-7

The shortfin mako, *Isurus oxyrinchus*, is caught in the eastern North Atlantic as a regular bycatch of the surface-drift longline fishery, mainly directed towards swordfish, *Xiphias gladius*. Stomachs of 112 shortfin mako sharks, ranging in size from 64 cm to 290 cm fork length, showed teleosts to be the principal component of the diet, occurring in 87% of the stomachs and accounting for over 90% of the contents by weight. Crustaceans and cephalopods were also relatively important in this species' diet, whereas other elasmobranchs were only present in lower percentages. Meal overlap was observed in half of the sampled sharks. No clear trend of prey size selectivity was found, despite smaller individuals seeming incapable of pursuing larger and faster prey. The retention of small prey was also observed in the diet of all sizes of shark. Seasonality in food habits was in accordance with the current availability of food items. The observed vacuity index of 12% is comparable to foraging ecology studies using gillnetting and appears not to be influenced by baited longline gear. Morphological relationships of the digestive system might add important information to the foraging ecology studies and to ecosystem modelling.

Malpica-Cruz, L., Herzka, S. Z., Sosa-Nishizaki, O., & Escobedo-Olvera, M. A. (2013). Tissue-Specific Stable Isotope Ratios of Shortfin Mako (*Isurus oxyrinchus*) and White (*Carcharodon carcharias*) Sharks as Indicators of Size-Based Differences in Foraging Habitat and Trophic Level. *Fisheries Oceanography, 22*(6), 429-445 https://doi.org/10.1111/fog.12034

We evaluated whether the trophic level and feeding grounds (coastal versus offshore) of white and shortfin mako sharks captured in the northern Mexican Pacific varied as a function of size using carbon (C-13 values) and nitrogen (N-15 values) stable isotope analysis of soft tissues. A step increase in N-15 values was observed at approximately 85cm TL and 150-170cm TL for shortfin mako and white sharks, respectively, consistent with the dilution of the maternal isotopic signal following the incorporation of exogenous food. Shortfin mako and white shark muscle tissue and whole blood were enriched in N-15 as a function of size, which is consistent with increasing trophic level, but this pattern may be confounded by differences in habitat. To infer differences in foraging habitat throughout life, we compared isotope ratios of liver and blood fractions with those of white muscle tissue; these tissues have relatively faster and slower isotope turnover rates, respectively. Whole blood and muscle C-13 values of small white sharks (<200cm total length) caught near the coast suggested benthic foraging. Very limited differences between C-13 values of muscle tissue and whole blood from small and medium mako (<196cm TL) and small white sharks indicated equilibrium to local feeding grounds. In contrast, differences in the C-13 values of liver tissue from small and medium mako and small white sharks indicated changes in diet or feeding grounds. The C-13 values of plasma and muscle tissue of large white sharks (>350cm total

length) caught offshore indicate feeding in coastal and oceanic areas and are consistent with recent migration to pelagic feeding grounds. Our study provides insight into size-based habitat use and migration patterns of two species of migratory sharks for which there is limited information, particularly in their nursery grounds in Mexican waters.

Maya Meneses, C. I., Torres Rojas, Y. E., Galván Magaña, F., Aguiñiga García, S., & Trasviña Carrillo, L. D. (2016). Trophic Overlap between Blue Sharks (*Prionace glauca*) and Shortfin Makos (*Isurus oxyrinchus*): Trophic Linkages between Two Shark Species in the Eastern Pacific Ocean Food Web. *Food Webs, 7*, 13-19 https://doi.org/10.1016/j.fooweb.2016.03.002

Trophic interactions in food webs must be considered in order to assess the trophic role of different species in the ecological network structure as well as the relationship between resource use and interactions between different organisms. Such studies provide important information for ecosystem-based fisheries management. Thus, our goal was to analyze the trophic overlap between blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) off the west coast of Baja California Sur, Mexico, in order to infer their diet preferences and spatial distribution. We sampled the dorsal white muscle of 39 P. glauca and 35 *I. oxyrinchus* in December 2009 and March 2011. No significant differences between sexes or maturity stage were identified for P. glauca from either sampling location, indicating similar foraging preferences. For *I. oxyrinchus*, there was a significant difference in the δ13C values for males and females, suggesting different foraging preferences or movement patterns. The trophic positions and the SIBER analysis assigned to both tertiary predators in this study indicate that P. glauca is a specialist, while *I. oxyrinchus* is a generalist. Significant differences were also identified in the δ15N and δ13C values for P. glauca and *I. oxyrinchus*, indicating low overlap between these two shark species. These patterns suggest that these two sharks have different trophic preferences and migratory histories; thus, each species plays a unique trophic role off the west coast of Baja California Sur, Mexico.

McKenzie, R. W., Motta, P. J., & Rohr, J. R. (2014). Comparative Squamation of the Lateral Line Canal Pores in Sharks. *Journal of Fish Biology, 84*(5), 1300-1311 https://doi.org/10.1111/jfb.12353

The current study collected the first quantitative data on lateral line pore squamation patterns in sharks and assessed whether divergent squamation patterns are similar to experimental models that cause reduction in boundary layer turbulence. In addition, the hypothesis that divergent orientation angles are exclusively found in fast-swimming shark species was tested. The posterior lateral line and supraorbital lateral line pore squamation of the fast-swimming pelagic shortfin mako shark *Isurus oxyrinchus* and the slow-swimming epi-benthic spiny dogfish shark Squalus acanthias was examined. Pore scale morphology and pore coverage were qualitatively analysed and compared. In addition, pore squamation orientation patterns were quantified for four regions along the posterior lateral line and compared for both species. *Isurus oxyrinchus* possessed consistent pore scale coverage among sampled regions and had a divergent squamation pattern with multiple scale rows directed dorsally and ventrally away from the anterior margin of the pore with an average divergent angle of 13 degrees for the first row of scales. Squalus acanthias possessed variable amounts of scale coverage among the sampled regions and had a divergent squamation pattern with multiple scale rows directed ventrally away from the anterior margin of the pore with an average angle of 19 degrees for the first row of scales. Overall, the squamation pattern measured in *I. oxyrinchus* fell within the parameters used in the fluid flow analysis, which suggests that this pattern may reduce boundary layer turbulence and affect lateral line sensitivity. The exclusively ventral oriented scale pattern seen in S. acanthias possessed a high degree of divergence but

the pattern did not match that of the fluid flow models. Given current knowledge, it is unclear how this would affect boundary layer flow. By studying the relationship between squamation patterns and the lateral line, new insights are provided into sensory biology that warrant future investigation due to the implications for the ecology, morphology and sensory evolution of sharks.

Monteiro, M. S., Vaske, J. T., Barbosa, T. M., & Alves, M. D. O. (2006). Predation by a Shortfin Mako Shark, *Isurus oxyrinchus*, Rafinesque, 1810, on a Pantropical Spotted Dolphin, *Stenella attenuata*, Calf in Central Atlantic Waters. *Latin American Journal of Aquatic Mammals, 5*(2) https://doi.org/10.5597/lajam00106

No abstract.

Nasby-Lucas, N., Dewar, H., Sosa-Nishizaki, O., Wilson, C., Hyde, J. R., Vetter, R. D., . . . Kohin, S. (2019). Movements of Electronically Tagged Shortfin Mako Sharks (*Isurus oxyrinchus*) in the Eastern North Pacific Ocean. *Animal Biotelemetry, 7*(1), 12 https://doi.org/10.1186/s40317-019-0174-6

Background: Most information on shortfin makos (*Isurus oxyrinchus*) in the eastern North Pacific (ENP) currently comes from fisheries data and short-term tracking studies. Although range has been inferred from catch and conventional tag data, little is known about the migration patterns and behavior in the ENP. This long-term electronic tagging study was designed to examine in detail the movement patterns and behavior of mako sharks in the ENP. Results: In this study, a total of 105 mako sharks (104–280 cm fork length) were successfully tagged in the California Current between 2002 and 2014 with Argos satellite tags, including 93 satellite-linked radio-transmitting (SLRT) tags and 71 pop-up satellite archival tags (PSATs). This included 29 males that are in the size range of maturity, but only one mature female. Mean track durations from SLRT data were 337 days (max 1025), and PSAT tags were 136 days (max 272). Estimated minimum distance traveled in 1 year ranged from 6945 to 18,800 km/year. Habitats utilized included the entire California Current, the Sea of Cortez and offshore in the areas of the North Pacific Subtropical Gyre, North Pacific Transition Zone and North Equatorial Current. Seasonal movements within the California Current coincided with periods of higher primary productivity and chlorophyll a, and sea surface temperatures (SSTs) between 15 and 25 °C. SST ranged from 11 to 31 °C throughout the range, indicating a broad thermal tolerance. Conclusions: Some of the key findings include the discovery of a high degree of variability between individuals in their vertical and horizontal movements, a strong influence of body size and season on mako shark movements, and the repetitive use of certain areas by individuals. These results expand our understanding of the distribution of mako sharks in the ENP. Although mako sharks are thought to comprise a single stock throughout the North Pacific, horizontal distribution of tagged mako sharks in this study was limited to the ENP demonstrating some spatial substructure. This study provides important data that can be used to identify fishery and gear vulnerabilities and inform management.

Nosal, A. P., Cartamil, D. P., Wegner, N. C., Lam, C. H., & Hastings, P. A. (2019). Movement Ecology of Young-of-the-Year Blue Sharks *Prionace glauca* and Shortfin Makos *Isurus oxyrinchus* within a Putative Binational Nursery Area. *Marine Ecology Progress Series, 623*, 99-115 https://doi.org/10.3354/meps13021

Managing pelagic shark stocks requires information about the movement patterns and fisheries interactions of all age classes, including young-of-the-year (YOY; age-0), which, for many species, is particularly scant. This study investigated the vertical and horizontal movements of YOY blue sharks *Prionace glauca* and shortfin makos *Isurus oxyrinchus* in the Southern California Bight (SCB) ecoregion using pop-up satellite archival tags (PSATs) and fishery data. Geolocation estimates from PSATs (n = 5 for each species) occurred entirely within the SCB ecoregion and exclusive economic zones of the USA and Mexico (mean tracking period: 46.1 +/- 24.8 d). YOY blue sharks spent 96.4% of their time at <40 m depth (60.4% <2 m) and exhibited reverse diel vertical migration (greater nighttime depths). YOY shortfin makos spent 97.0% of their time at <40 m (24.8% <2 m) and exhibited a 'midday dip' of 5-10 m below the surface, centered around solar noon. These differences in vertical movements likely reflect foraging tactics. Additionally, observer data from the California drift gillnet fishery suggest juvenile blue sharks and shortfin makos move seasonally along the coast, northward from late summer to early fall and southward from late autumn to early winter. Age classes for both species exhibited latitudinal segregation, with smaller blue sharks and larger shortfin makos found farther north. The SCB ecoregion has long been regarded as a nursery area for both species; however, our data, in combination with previous studies, suggest this important habitat is much more extensive, comprising the highly productive continental margins spanning approximately 27.7-46.2 degrees N for blue sharks and 23.4-34.5 degrees N for shortfin makos.

Preti, A., Soykan, C. U., Dewar, H., Wells, R. J. D., Spear, N., & Kohin, S. (2012). Comparative Feeding Ecology of Shortfin Mako, Blue and Thresher Sharks in the California Current. *Environmental Biology of Fishes, 95*(1), 127-146 https://doi.org/10.1007/s10641-012-9980-x

This study describes the feeding ecology of three pelagic shark species in the California Current: shortfin mako (*Isurus oxyrinchus*); blue (*Prionace glauca*); and thresher (*Alopias vulpinus*) sharks. Stomach contents of sharks collected from 2002 to 2008 were identified to the lowest taxonomic level and analyzed using univariate and multivariate methods. Of 330 mako sharks sampled (53 to 248 cm fork length [FL]), 238 stomachs contained 42 prey taxa, with jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) representing the most important prey based on the geometric index of importance (GII). In addition, 158 blue sharks were sampled (76 to 248 cm FL) and 114 stomachs contained 38 prey taxa, with jumbo and Gonatus spp. squids representing the most important prey. Lastly, 225 thresher sharks were sampled (108 to 228 cm FL) and 157 stomachs contained 18 prey taxa with northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) identified as the most important prey. Overall, mako sharks had the most diverse diet based upon Simpson's diversity index (1/D) (8.43 +/- 1.16), feeding on many species of teleosts and cephalopods, followed by blue sharks (6.20 +/- 2.11) which consumed a wide range of prey (primarily cephalopods), while thresher sharks were most specialized (2.62 +/- 0.34), feeding primarily on coastal pelagic teleosts. Dietary overlap was lowest between blue and thresher sharks (Sorensen similarity index = 0.321 and Simplified Morisita Horn index = 0.006), and seasonal variability in diet was greatest for blue sharks (Simplified Morisita Horn index = 0.260, Analysis of Similarity (ANOSIM) $p < 0.001$). In addition, size class, and subregion were significant factors that affected diet of each species differently (ANOSIM $p < 0.001$). Despite similarities in life history characteristics and spatial and temporal overlap in habitat, diets of these three common shark species are distinct in the California Current.

Quigley, D. T. G., Hannon, G., & Collins, T. (2015). Shortfin Mako Shark (*Isurus oxyrinchus* Rafinesque), in Irish Waters. *The Irish Naturalists' Journal, 34*(2), 146-148 Retrieved from http://www.jstor.org/stable/44577812

No abstract.

Randall, J. E., & Levy, M. F. (1976). A near-Fatal Shark Attack by a Mako in the Northern Red Sea. *Israel Journal of Ecology and Evolution, 25*(1-2), 61-70 https://doi.org/10.1080/00212210.1976.10688427

On 7 September 1974 a girl swimmer, aged 20, and a male companion swam about 500 m offshore from North Beach, Hat, Red Sea. At about 5 p.m. the girl was attacked by a shark of about 2 m length. She was bitten approximately 12 times by the shark before being rescued. Most of the wounds were on the distal half of the limbs; surprisingly, almost no tissue was removed by the shark. The girl barely survived; ultimately it was necessary to amputate her lower left arm. Two days later a shortfin mako shark (*Isurus oxyrinchus*), 2.33 m total length, was caught in a wier at Elat. Mako teeth are long and prong-like without serrations. Comparison of an imprint of the shark's teeth in plastic to the tooth marks from a bite on the victim's right thigh revealed that a mako of the same size, very possibly the same shark, had bitten her. Three shark attacks which had been attributed to makos are shown to involve other species. Two other incidents in which mako identity seems certain resulted in contact with humans, but no wounds. The Elat attack appears to be the first for which a mako has positively been identified as inflicting wounds on man.

Rangel, B. D., Salmon, T., Poscai, A. N., Kfoury, J. R., & Rici, R. E. G. (2019). Comparative Investigation into the Morphology of Oral Papillae and Denticles of Four Species of Lamnid and Sphyrnid Sharks. *Zoomorphology, 138*(1), 127-136 https://doi.org/10.1007/s00435-018-0427-6

The microstructures of the oral cavity in sharks have received relatively little study, despite their potential functional importance for gustation, feeding, and ventilation. Accordingly, here we conducted a preliminary comparative investigation into the structure and organization of oral papillae and denticles found on the ventral surface of the oral cavity in four species of shark (bigeye thresher, shortfin mako, scalloped hammerhead, and smooth hammerhead). Despite a limited sample size, differences in complexity and ornamentation of oral papillae and denticles were found across the four species. The scalloped hammerhead shark exhibited the largest oral papillae compared to the bigeye thresher and the shortfin mako. The most complex oral denticles, in terms of number of ridges and microstructures, were found in the scalloped hammerhead, followed by the bigeye thresher, smooth hammerhead and shortfin mako. For smooth hammerheads, in which samples were available from both juveniles and adults, differences in denticle microstructures were found suggesting possible ontogenetic variations. These results suggest that shape, size and arrangement of oral papillae and denticles may be related to ecology and phylogeny of the species studied. Based on these emerging patterns we discuss several plausible hypotheses relating to the function of these structures for consideration in future studies.

Rogers, P. J., Huveneers, C., Page, B., Hamer, D. J., Goldsworthy, S. D., Mitchell, J. G., & Seuront, L. (2012). A Quantitative Comparison of the Diets of Sympatric Pelagic Sharks in Gulf and Shelf Ecosystems Off Southern Australia. *ICES Journal of Marine Science, 69*(8), 1382-1393 https://doi.org/10.1093/icesjms/fss100

Predator-prey dynamics represent an important determinant in the functioning of marine ecosystems. This study provides the first quantitative investigation of the diets of sympatric pelagic shark species in gulf and shelf waters off southern Australia. Stomachs of 417 sharks collected from fishery catches between 2007 and 2011 were examined, including 250 bronze whalers, 52 shortfin makos, 49 dusky sharks, 39 smooth hammerheads, and 27 common threshers. Dusky sharks had the highest dietary diversity of the five species examined. We found overlap in the consumption of cephalopods, small pelagic teleosts, crustaceans, and benthic teleosts in bronze whalers, dusky sharks, and smooth hammerheads, and preliminary evidence of specialization in the highly migratory species, the common thresher and the shortfin mako. Findings were discussed and compared with previous studies in other temperate marine ecosystems. This study will significantly improve the understanding of the ecological roles of these top predators in the gulf and shelf habitats off southern Australia, and enhance the ecosystem models being developed for this unique bioregion.

Stevens, J. D. (1983). Observations on Reproduction in the Shortfin Mako *Isurus oxyrinchus*. *Copeia, 1983*(1), 126-130 https://doi.org/10.2307/1444706

Ninety one *Isurus oxyrinchus* were examined from New South Wales Australia. Males attain sexual maturity at 195 cm total length; females mature at 280 cm. Data obtained from gravid and mature non-gravid specimens confirms that *I. oxyrinchus* is oviphagous. Size at birth is about 70 cm and litter sizes vary from 4 to 16. Parturition off New South Wales probably occurs in November. The length (L)/weight (W) relationship for *I. oxyrinchus* is described by the equation W = 4.832 x 10-6,L

Stewardson, C. L. (1999). Preliminary Investigations of Shark Predation on Cape Fur Seals *Arctocephalus pusillus pusillus* from the Eastern Cape Coast of South Africa. *Transactions of the Royal Society of South Africa, 54*, 191-203 https://doi.org/10.1080/00359199909520624

Shark predation on Cape fur seals, *Arctocephalus pusillus pusillus*, from the Eastern Cape coast of South Africa was investigated. Observations were made on an opportunistic basis over a five year period from 1991 to 1996. Evidence of shark predation was obtained from: (1) incidental observations of shark attacks on live Cape fur seals, and (2) counts of shark bite wounds on the bodies of live and dead seals. In Eastern Cape waters, potential shark predators include the white, *Carcharodon carcharias*; broadnose sevengill, *Notorynchus cepedianus*; bluntnose sixgill, *Hexanchus griseus*, shortfin mako, *Isurus oxyrinchus*; bull, *Carcharhinus leucas*; tiger, *Galeocerdo cuvier*: and dusky, *Carcharhinus obscurus*. Only the white and broadnose sevengill shark have been observed actively feeding on Cape fur seals. Shark bitten seals (n = 33) were observed throughout the year, with coastal records peaking in the autumn/winter period. Adult animals were observed with shark bite wounds more often than young. Wounds were usually located on the lower body, suggesting that attacks were made from behind. Fresh shark bite wounds were found on a minimum of 3.4% of seals found stranded on local beaches, and 0.3% of seals observed at the Black Rocks colony during the breeding season. Although predatory encounters appear to be common, long term studies are required before we can fully assess the extent

of shark predation along the Eastern Cape coast. These records are the only known examples of shark inflicted injuries on southern fur seals Arctocephalus spp. south of 10 degrees S.

Stillwell, C. E., & Kohler, N. E. (1982). Food, Feeding-Habits, and Estimates of Daily Ration of the Shortfin Mako (*Isurus oxyrinchus*) in the Northwest Atlantic. *Canadian Journal of Fisheries and Aquatic Sciences, 39*(3), 407-414 https://doi.org/10.1139/f82-058

Analyses of the stomach contents of 399 male and female mako sharks (*Isurus oxyrinchus*) ranging from 67 to 328 cm are presented. Samples are from shark fishing tournaments held in New Jersey, New York, Rhode Island, and from longline catches taken between Cape Hatteras and the Grand Banks. Teleost remains occur in 67% of the stomachs with bluefish (*Pomatomus saltatrix*) constituting 77.5% of the diet by volume. Bluefish is the major inshore food item. Cephalopoda amount to 15% of the stomach contents by frequency of occurrence and are consumed primarily offshore. Consumption and diet are the same for both sexes. The average capacity of the stomach is 10% of the body weight. Estimates of daily ration average 2 kg (range from 1.4 to 2.7 kg). Makos may consume 4.3 to 14.5% of the available bluefish resource in the area between Cape Hatteras, NC, and Georges Bank.

Suk, S. H., Smith, S. E., & Ramon, D. A. (2009). Bioaccumulation of Mercury in Pelagic Sharks from the Northeast Pacific Ocean. *California Cooperative Oceanic Fisheries Investigations Reports, 50*, 172-177 Retrieved from https://calcofi.org/ccpublications/ccreports/calcofi-reports-toc/188-crtoc-vol-50-2009.html

The common thresher, *Alopias vulpinus*, and shortfin mako, *Isurus oxyrinchus*, are large pelagic shirk species frequently targeted by sport and commercial fisheries Being top marine predators, the common thresher and shortfin mako are susceptible to bioaccumulation of heavy elements in their tissues We investigated the levels of mercury (Hg) in the tissues of these sharks from the central and eastern North Pacific Ocean and how those levels reflect their feeding ecology For both species we found detectable levels of Hg in the white muscle but not in the liver, and no differences in Hg levels between the sexes, which suggests similar feeding patterns There was, however, a significant interspecific difference with the shortfin mako having considerably higher Hg levels than the common thresher This likely reflects the shortfin mako's opportunistic feeding on higher trophic level prey, such as jumbo squid (*Dosidicus gigas*), relative to the common thresher which primarily targets smaller schooling fish We found strong linear relationships between body size and Hg level for both species with a significantly greater rate of increase for the shortfin mako which also may suggest a higher daily ration In all common thresher samples, Hg levels were well below the U S Food and Drug Administration's established action level of 1 0 mu g/g for commercial fish Nearly all shortfin mako muscle samples from sharks <= 150 cm fork length (FL) had Hg levels below 1 0 mu g/g, but all shortfin mako >150 cm FL had muscle Hg levels exceeding this level, with the largest sharks having nearly three times this level

Tamburin, E., Kim, S. L., Elorriaga-Verplancken, F. R., Madigan, D. J., Hoyos-Padilla, M., Sanchez-Gonzalez, A., . . . Galvan-Magana, F. (2019). Isotopic Niche and Resource Sharing among Young Sharks (*Carcharodon carcharias* and *Isurus oxyrinchus*) in Baja California, Mexico. *Marine Ecology Progress Series, 613*, 107-124 https://doi.org/10.3354/meps12884

White sharks *Carcharodon carcharias* and shortfin mako sharks *Isurus oxyrinchus* are globally distributed apex predators and keystone species. However, regional information regarding juvenile biology, such as habitat preferences and trophic ecology, is lacking. This study investigates habitat use and feeding ecology of juvenile shortfin mako and white sharks in an aggregation site with high catch of these species by artisanal fisheries in Sebastian Vizcaino Bay (SVB; Baja California, Mexico) using stable isotope analysis (SIA) of carbon (delta C-13) and nitrogen (delta N-15). During 2015 and 2016, we collected muscle samples from newborn, young of the year, and juvenile shortfin mako and white sharks from individuals with similar body size, as well as local prey, to develop a conceptual foraging framework based on SIA. We found a positive relationship between shortfin mako length and delta N-15 values, indicating ontogenetic changes in diet based on prey or locality. Bayesian isotopic mixing models (MixSIR) using prey from different regions in the North Eastern Pacific suggested diet shifts in shortfin makos from offshore, northern habitats to inshore habitats of southern Baja (e.g. SVB), while analysis of white sharks reflected use of inshore habitats of both southern California, northern Baja, and SVB. Our results suggest shared resource use between these shark species and potentially high consumption of prey from SVB and other similar coastal regions in southern Baja. This study characterizes high use of inshore regions for juvenile shortfin mako and white sharks, which has important implications for management and conservation practices.

Teffer, A. K., Staudinger, M. D., Taylor, D. L., & Juanes, F. (2014). Trophic Influences on Mercury Accumulation in Top Pelagic Predators from Offshore New England Waters of the Northwest Atlantic Ocean. *Marine Environmental Research, 101*, 124-134 https://doi.org/10.1016/j.marenvres.2014.09.008

Trophic pathways and size-based bioaccumulation rates of total mercury were evaluated among recreationally caught albacore tuna (*Thunnus alalunga*), yellowfin tuna (*Thunnus albacares*), shortfin mako shark (*Isurus oxyrinchus*), thresher shark (*Alopias vulpinus*), and dolphinfish (*Coryphaena hippurus*) from offshore southern New England waters of the northwest Atlantic Ocean between 2008 and 2011. Mercury concentrations were highest in mako (2.65 +/- 1.16 ppm) and thresher sharks (0.87 +/- 0.71 ppm), and significantly lower in teleosts (albacore, 0.45 +/- 0.14 ppm; yellowfin, 0.32 +/- 0.09 ppm; dolphinfish, 0.20 +/- 0.17 ppm). The relationship between body size and mercury concentration was positive and linear for tunas, and positive and exponential for sharks and dolphinfish. Mercury increased exponentially with delta (15)N values, a proxy for trophic position, across all species. Results demonstrate mercury levels are positively related to size, diet and trophic position in sharks, tunas, and dolphinfish, and the majority of fishes exhibited concentrations greater than the US EPA recommended limit.

Vaudo, J. J., Wetherbee, B. M., Wood, A. D., Weng, K., Howey-Jordan, L. A., Harvey, G. M., & Shivji, M. S. (2016). Vertical Movements of Shortfin Mako Sharks *Isurus oxyrinchus* in the Western North Atlantic Ocean Are Strongly Influenced by Temperature. *Marine Ecology Progress Series, 547*, 163-175 https://doi.org/10.3354/meps11646

Although shortfin mako sharks *Isurus oxyrinchus* are regularly encountered in pelagic fisheries, limited information is available on their vertical distribution and is primarily restricted to cooler areas of their geographic range. We investigated the vertical movements of mako sharks across differing temperature regimes within the western North Atlantic by tagging 8 individuals with pop-up satellite archival tags off the northeastern United States and the Yucatan Peninsula, Mexico. Depth and temperature records

across 587 d showed vertical movements strongly associated with ocean temperature. Temperatures <15 degrees C created a lower depth limit to most diving behaviors, and shifts in depths used coincided with changes in the thermal properties of the vertical habitat. In the warmest water columns, sharks spent 36% of the daytime at depths >150 m compared to only 1% in the coldest water columns. The sharks showed diel diving behavior, with deeper dives occurring primarily during the daytime (maximum depth: 866 m). Overall, sharks experienced temperatures between 5.2 and 31.1 degrees C. When the opportunity was available, sharks spent considerable time in waters ranging from 22 to 27 degrees C, indicating underestimation of the previously reported upper limit of the mako sharks' preferred temperature. The preference for higher temperatures does not support endothermy as an adaption for niche expansion in mako sharks. The strong influence of thermal habitat on movement behavior suggests potentially strong impacts of rising ocean temperatures on the ecology of this highly migratory top predator.

Visser, I. N., Berghan, J., van Meurs, R., & Fertl, D. (2000). Killer Whale (Orcinus Orca) Predation on a Shortfin Mako Shark (*Isurus oxyrinchus*) in New Zealand Waters. *Aquatic Mammals, 26*(3), 229-231 Retrieved from https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=31&Itemid=57

Observations of killer whale (*Orcinus orca*) predation on elasmobranchs are not common. We report on a group of seven killer whales in New Zealand waters capturing a shortfin mako shark (*Isurus oxyrinchus*), a species previously not reported as prey of killer whales. Elasmobranchs have been suggested as a main prey item for New Zealand killer whales and the addition of this species to the prey list helps to support this theory.

Wood, A. D., Collie, J. S., & Kohler, N. E. (2007). Estimating Survival of the Shortfin Mako *Isurus oxyrinchus* (Rafinesque) in the North-West Atlantic from Tag-Recapture Data. *Journal of Fish Biology, 71*(6), 1679-1695 https://doi.org/10.1111/j.1095-8649.2007.01634.x

Survival was estimated for shortfin mako *Isurus oxyrinchus* in the north-west Atlantic from tag-recapture data. The data used in this study were collected by the National Marine Fisheries Service Cooperative Shark Tagging Programme from 1962 to 2003. In total, 6309 shortfin mako sharks were tagged, of which 730 were recaptured. The high recapture rate of 11.6% for this species provided adequate recapture data to carry out survival analyses. Estimates of survival were generated with the computer software MARK, which provided a means for estimating parameters from tagged animals when they were recaptured. The results of several models are presented with various combinations of constant and time-specific survival and recovery rates. A parametric bootstrap and the median variance inflation factor ((c) over cap) approach were used to test the fit of the general model to the data. The estimated (c) over cap indicated a very good model fit. The models with time invariant survival rate had the most support from the data and no group or time period effects were found. Recovery rate (f) appeared to increase from 0.043 in the early years to 0.056 in the later years. The nominal survival rate of 0.59 year(-1) was adjusted with an estimated tag-shedding rate of 0.26 year(-1) to generate a final corrected annual survival estimate of 0.79 with a 95% CI of 0.71-0.87.

Section III: Genetics

Bernal, D., Carlson, J. K., Goldman, K. J., & Lowe, C. G. (2012). Energetics, Metabolism, and Endothermy in Sharks and Rays. In *Biology of Sharks and Their Relatives, 2nd Edition.* J. C. Carrier, J. A. Musick, & M. R. Heithaus (Eds.), (pp. 211-237) https://doi.org/10.1201/b11867

During the last several decades, studies on the aerobic metabolism of elasmobranchs have relied on the use of indirect calorimetry centered on small, generally sedentary species that acclimate well to the tight enclosures of a respirometer chamber and those that are easily maintained in captivity for long periods of time. By contrast, work on larger and obligate ram ventilating species has lagged far behind and typically features a paucity of measurements usually conducted over short durations of time on a few selected species. More recently, eldbased empirical models have been used to estimate the metabolic requirements of species too large to work with in the laboratory. The original view of the energetic demands in sharks and rays was that they typically possessed lower metabolic rates relative to similar sized teleosts; however, this view is beginning to change as new data emerge on the metabolism of several large, actively swimming species. Nonetheless, several general important factors need to be considered when attempting to compare the energetic demands between elasmobranchs and teleosts and among elasmobranchs.

Blanco, M., Perez-Martin, R. I., & Sotelo, C. G. (2008). Identification of Shark Species in Seafood Products by Forensically Informative Nucleotide Sequencing (Fins). *J Agric Food Chem, 56*(21), 9868-9874 https://doi.org/10.1021/jf8015128

The identification of commercial shark species is a relevant issue to ensure the correct labeling of seafood products, to maintain consumer confidence in seafood, and to enhance the knowledge of the species and volumes that are at present being captured, thus improving the management of shark fisheries. The polymerase chain reaction was employed to obtain a 423 bp amplicon from the mitochondrial cytochrome b gene. The sequences from this fragment, belonging to 63 authentic individuals of 23 species, were analyzed using a genetic distance method. Nine different samples of commercial fresh, frozen, and convenience food were obtained in local and international markets to validate the methodology. These samples were analyzed, and sequences were employed for species identification, showing that forensically informative nucleotide sequencing (FINS) is a suitable technique for identification of processed seafood containing shark as an ingredient. The results also showed that incorrect labeling practices may occur regarding shark products, probably because of incorrect labeling at the production point.

Blower, D. C., Pandolfi, J. M., Bruce, B. D., Gomez-Cabrera, M. D., & Ovenden, J. R. (2012). Population Genetics of Australian White Sharks Reveals Fine-Scale Spatial Structure, Transoceanic Dispersal Events and Low Effective Population Sizes. *Marine Ecology Progress Series, 455*, 229-244 https://doi.org/10.3354/meps09659

Despite international protection of white sharks *Carcharodon carcharias*, important conservation parameters such as abundance, population structure and genetic diversity are largely unknown. The tissue of 97 predominately juvenile white sharks sampled from spatially distant eastern and southwestern Australian coastlines was sequenced for the mitochondrial DNA (mtDNA) control region and genotyped with 6 nuclear-encoded microsatellite loci. MtDNA population structure was found

between the eastern and southwestern coasts (F-ST = 0.142, p < 0.0001), implying female reproductive philopatry. This concurs with recent satellite and acoustic tracking findings which suggest the sustained presence of discrete east coast nursery areas. Furthermore, population subdivision was found between the same regions with biparentally inherited micro satellite markers (F-ST = 0.009, p < 0.05), suggesting that males may also exhibit some degree of reproductive philopatry; 5 sharks captured along the east coast had mtDNA haplotypes that resembled western Indian Ocean sharks more closely than Australian/New Zealand sharks, suggesting that transoceanic dispersal, or migration resulting in breeding, may occur sporadically. Our most robust estimate of contemporary genetic effective population size was low and close to thresholds at which adaptive potential may be lost. For a variety of reasons, these contemporary estimates were at least 1, possibly 2, orders of magnitude below our historical effective size estimates. Population decline could expose these genetically isolated populations to detrimental genetic effects. Regional Australian white shark conservation management units should be implemented until genetic population structure, size and diversity can be investigated in more detail.

Cardenosa, D. (2019). Genetic Identification of Threatened Shark Species in Pet Food and Beauty Care Products. *Conservation Genetics, 20*(6), 1383-1387 https://doi.org/10.1007/s10592-019-01221-0

Contemporary global demand for shark commodities such as fins, meat, and liver oil, is arguably the main driver of shark overexploitation trends observed in the last three decades. Shark are most commonly traded for their fins to be used in different Asian countries as a soup delicacy. Nevertheless, shark meat trade has increased substantially in the last decade, while liver oil trade is still largely unknown. Shark liver oil is highly valuable in the cosmetic industry as a moisturizer, while shark meat is directly consumed in a large number of countries but the whole extent of its uses is unknown. Here I used a multiplex mini-barcode PCR protocol to identify traces of shark DNA in beauty care and pet food products, in order to identify them to the genus and/or species level. All products tested for this study were not labeled as containing elasmobranch-based ingredients. I tested 87 pet food products, 63% amplified successfully, and 70% of those were identified as the Endangered shortfin mako shark. I also tested twenty-four cosmetics, where 3 (12.5%) amplified successfully, containing blue shark, scalloped hammerhead and blacktip shark. This study highlights the need for more labeling controls, since shark populations could benefit if consumers have the alternative to choose whether or not to purchase products containing threatened shark species in order to decrease the global demand.

Cardenosa, D., Hyde, J., & Caballero, S. (2014). Genetic Diversity and Population Structure of the Pelagic Thresher Shark (*Alopias pelagicus*) in the Pacific Ocean: Evidence for Two Evolutionarily Significant Units. *PLOS ONE, 9*(10), e110193 https://doi.org/10.1371/journal.pone.0110193

There has been an increasing concern about shark overexploitation in the last decade, especially for open ocean shark species, where there is a paucity of data about their life histories and population dynamics. Little is known regarding the population structure of the pelagic thresher shark, *Alopias pelagicus*. Though an earlier study using mtDNA control region data, showed evidence for differences between eastern and western Pacific populations, the study was hampered by low sample size and sparse geographic coverage, particularly a lack of samples from the central Pacific. Here, we present the population structure of *Alopias pelagicus* analyzing 351 samples from six different locations across the Pacific Ocean. Using data from mitochondrial DNA COI sequences and seven microsatellite loci we found evidence of strong population differentiation between western and eastern Pacific populations and

evidence for reciprocally monophyly for organelle haplotypes and significant divergence of allele frequencies at nuclear loci, suggesting the existence of two Evolutionarily Significant Units (ESU) in the Pacific Ocean. Interestingly, the population in Hawaii appears to be composed of both ESUs in what seems to be clear sympatry with reproductive isolation. These results may indicate the existence of a new cryptic species in the Pacific Ocean. The presence of these distinct ESUs highlights the need for revised management plans for this highly exploited shark throughout its range.

Carreon-Zapiain, M. T., Tavares, R., Favela-Lara, S., & Onate-Gonzalez, E. C. (2020). Ecological Risk Assessment with Integrated Genetic Data for Three Commercially Important Shark Species in the Mexican Pacific. *Regional Studies in Marine Science, 39* https://doi.org/10.1016/j.rsma.2020.101431

Sharks are highly vulnerable species due to their biological characteristics. Productivity and Susceptibility Analysis (PSA) is a useful method to assess the vulnerability of shark populations to prioritize management strategies. Given that molecular and genetic tools have played an important role in the conservation of vulnerable populations and species, the objective of this study was to evaluate the ecological risk of *Prionace glauca*, *Isurus oxyrinchus*, and *Alopias vulpinus* in the Mexican Pacific by incorporating genetic information into PSA. We hypothesized that the integration of genetic variables such as genetic structure and diversity (Fst, h, and pi), in a PSA will allow us to discriminate species with the same vulnerability index. The results of PSA-1 indicated that *I. oxyrinchus*, and A. vulpinus were at high ecological risk with identical vulnerability values (v = 2.2). Our results suggest that PSA with the combination of genetic attributes could be a useful tool for the application of conservation strategies or management policies, making easier the interpretation of results when the productivity or susceptibility attributes do not provide enough variation to prioritize between species or populations analyzed. Nevertheless, more studies that combine fishery and genetic information of commercially important sharks are needed.

Chang, C. H., Shao, K. T., Lin, Y. S., Tsai, A. Y., Su, P. X., & Ho, H. C. (2015). The Complete Mitochondrial Genome of the Shortfin Mako, *Isurus oxyrinchus* (Chondrichthyes, Lamnidae). *Mitochondrial DNA, 26*(3), 475-476 https://doi.org/10.3109/19401736.2013.834430

The complete mitochondrial genome of the shortfin mako (*Isurus oxyrinchus*) was determined by using a PCR-based method. The total length of mitochondrial DNA is 16,701 bp and includes 13 protein-coding genes, 2 ribosomal RNA, 22 transfer RNA genes, 1 replication origin region, and 1 control region. The mitochondrial gene arrangement of the tiger tail seahorse is also matching the one observed in the most vertebrate creatures. Base composition of the genome is A (28.8%), T (28.0%), C (28.0%), and G (15.2%) with an A + T rich hallmark as that of other vertebrate mitochondrial genomes.

Clarke, S. C., Magnussen, J. E., Abercrombie, D. L., McAllister, M. K., & Shivji, M. S. (2006). Identification of Shark Species Composition and Proportion in the Hong Kong Shark Fin Market Based on Molecular Genetics and Trade Records. *Conservation Biology, 20*(1), 201-211 https://doi.org/10.1111/j.1523-1739.2005.00247.x

The burgeoning and largely unregulated trade in shark fins represents one of the most serious threats to shark populations worldwide. In Hong Kong, the world's largest shark fin market, fins are classified by

traders into Chinese-name categories on the basis of market value, but the relationship between market category and shark species is unclear preventing identification of species that are the most heavily traded. To delineate these relationships, we designed a sampling strategy for collecting statistically sufficient numbers of fins from traders and categories under conditions of limited market access because of heightened trader sensitivities. Based on information from traders and morphological inspection, we hypothesized matches between market names and shark taxa for fins within 11 common trade categories. These hypotheses were tested using DNA-based species identification techniques to determine the concordance between market category and species. Only 14 species made up approximately 40% of the auctioned fin weight. The proportion of samples confirming the hypothesized match, or concordance, varied from 0.64 to 1 across the market categories. We incorporated the concordance information and available market auction records for these categories into stochastic models to estimate the contribution of each taxon by weight to the fin trade. Auctioned fin weight was dominated by the blue shark (*Prionace glauca*), which was 17% of the overall market. Other taxa, including the shortfin mako (*Isurus oxyrinchus*), silky (*Carcharhinus falciformis*), sandbar (*C. obscurus*), bull (*C. leucas*), hammerhead (*Sphyrna spp.*), and thresher (*Alopias spp.*), were at least 2-6% of the trade. Our approach to marketplace monitoring of wildlife products isparticularly applicable to situations in which quantitative data at the source of resource extraction are sparse and large-scale genetic testing is limited by budgetary or other market access constraints.

Corrigan, S., Kacev, D., & Werry, J. (2015). A Case of Genetic Polyandry in the Shortfin Mako *Isurus oxyrinchus*. *Journal of Fish Biology, 87*(3), 794-798 https://doi.org/10.1111/jfb.12743

This article documents a case of genetic polyandry in the oceanic and pelagic shortfin mako *Isurus oxyrinchus* and briefly comments on the implications of this finding.

Heist, E. J., Musick, J. A., & Graves, J. E. (1996). Genetic Population Structure of the Shortfin Mako (*Isurus oxyrinchus*) Inferred from Restriction Fragment Length Polymorphism Analysis of Mitochondrial Dma. *Canadian Journal of Fisheries and Aquatic Sciences, 53*(3), 583-588 https://doi.org/10.1139/cjfas-53-3-583

Restriction fragment length polymorphism analysis of mitochondrial DNA was used to investigate genetic population structure within the shortfin mako (*Isurus oxyrinchus*). Tissue samples from 21-30 shortfin makos were collected from each of five locations, two within the North Atlantic, one in the South Atlantic, one in the North Pacific, and one in the South Pacific. Mitochondrial DNA was digested with a panel of nine restriction enzymes to determine mitochondrial DNA haplotypes for each individual. Highly significant heterogeneity of haplotype distribution was detected in the shortfin mako (chi(2) probability of equal haplotype frequencies, $p < 0.001$). The pooled samples of North Atlantic shortfin mako appeared to be isolated from those from other oceans ($p < 0.001$). The nine restriction enzymes detected a haplotype diversity of 0.755 and a nucleotide sequence diversity of 0.347. There is no evidence of multiple subspecies of shortfin mako, nor of any past genetic isolation between shortfin mako populations.

Mangena, T., Jordaan, B. P., & Dippenaar, S. M. (2014). Phylogenetic Relationships and Genetic Diversity of Nemesis Risso, 1826 Species Found on Different Elasmobranch Host Species Off the Kwazulu-

Natal Coast, South Africa. *African Journal of Marine Science, 36*(2), 163-173 https://doi.org/10.2989/1814232x.2014.912992

Members of the order Siphonostomatoida (Copepoda) are generally poorly described from South African waters. Nemesis is one of 12 genera in the family Eudactylinidae and includes about nine species. In this study, we investigated whether there is any population structure among Nemesis lamna individuals infecting the white shark *Carcharodon carcharias* and the shortfin mako *Isurus oxyrinchus* according to host species or capture locality on the KwaZulu-Natal coast, South Africa. Additionally, we estimated the genetic diversity and the phylogenetic relationships among different Nemesis individuals collected from seven elasmobranch host species. Collected specimens were preserved in 70% ethanol and DNA was extracted, whereafter a fragment of the mitochondrial cytochrome oxidase I (COI) gene was amplified. Sequenced polymerase chain reaction products were aligned and analysed. The total dataset consisted of 34 newly generated COI sequences, four GenBank sequences and Eudactylina pusilla as an outgroup. There was no indication of grouping or population structure among the N. lamna individuals in terms of their host species or capture locality. The estimated topologies confirmed the division of Nemesis individuals into a N. lamna group and a Nemesis spp. group consisting of smaller individuals. These smaller Nemesis spp. individuals from five different host species seemed to represent three different species.

Marin, A., Serna, J., Robles, C., Ramirez, B., Reyes-Flores, L. E., Zelada-Mazmela, E., . . . Alfaro, R. (2018). A Glimpse into the Genetic Diversity of the Peruvian Seafood Sector: Unveiling Species Substitution, Mislabeling and Trade of Threatened Species. *PLOS ONE, 13*(11), e0206596 https://doi.org/10.1371/journal.pone.0206596

Peru is one of the world's leading fishing nations and its seafood industry relies on the trade of a vast variety of aquatic resources, playing a key role in the country's socio-economic development. DNA barcoding has become of paramount importance for systematics, conservation, and seafood traceability, complementing or even surpassing conventional identification methods when target organisms show similar morphology during the early life stages, have recently diverged, or have undergone processing. Aiming to increase our knowledge of the species diversity available across the Peruvian supply chain (from fish landing sites to markets and restaurants), we applied full and mini-barcoding approaches targeting three mitochondrial genes (COI, 16S, and 12S) and the control region to identify samples purchased at retailers from six departments along the north-central Peruvian coast. DNA barcodes from 131 samples were assigned to 55 species (plus five genus-level taxa) comprising 47 families, 24 orders, and six classes including Actinopterygii (45.03%), Chondrichthyes (36.64%), Bivalvia (6.87%), Cephalopoda (6.11%), Malacostraca (3.82%), and Gastropoda (1.53%). The identified samples included commercially important pelagic (anchovy, bonito, dolphinfish) and demersal (hake, smooth-hound, Peruvian rock seabass, croaker) fish species. Our results unveiled the marketing of protected and threatened species such as whale shark, Atlantic white marlin, smooth hammerhead (some specimens collected during closed season), shortfin mako, and pelagic thresher sharks. A total of 35 samples (26.72%) were mislabeled, including tilapia labeled as wild marine fish, dolphinfish and hake labeled as grouper, and different shark species sold as "smooth-hounds". The present study highlights the necessity of implementing traceability and monitoring programs along the entire seafood supply chain using molecular tools to enhance sustainability efforts and ensure consumer choice.

Natanson, L. J., Wintner, S. P., Johansson, F., Piercy, A., Campbell, P., De Maddalena, A., . . . Wedderburn-Maxwell, A. (2008). Ontogenetic Vertebral Growth Patterns in the Basking Shark *Cetorhinus maximus*. *Marine Ecology Progress Series, 361*, 267-278 https://doi.org/10.3354/meps07399

Age and growth of the basking shark *Cetorhinus maximus* (Gunnerus) was examined using vertebral samples from 13 females (261 to 856 cm total length [TL]), 16 males (311 to 840 cm TL) and 11 specimens of unknown sex (376 to 853 cm TL). Vertebral samples were obtained worldwide from museums and institutional and private collections. Examination of multiple vertebrae from along the vertebral column of 10 specimens indicated that vertebral morphology and band pair (alternating opaque and translucent bands) counts changed dramatically along an individual column. Smaller sharks had similar band pair counts along the length of the vertebral column while large sharks had a difference of up to 24 band pairs between the highest and lowest count along the column. Our evidence indicates that band pair deposition may be related to growth and not time in this species and thus the basking shark cannot be directly aged using vertebral band pair counts.

Palumbi, S. R., Robinson, K. M., Van Houtan, K. S., & Jorgensen, S. J. (2018). DNA Analysis of a Large Collection of Shark Fins from a Us Retail Shop: Species Composition, Global Extent of Trade and Conservation - a Technical Report from the Monterey Bay Aquarium. *bioRxiv*, 433847 https://doi.org/10.1101/433847

We identified shark fins sampled across the entirety of a shark fin shop that had operated on the west coast of the United States until 2014. From these specimens we obtained 963 species identifications with Cytochrome oxidase (COI) sequencing and 1,720 identifications with control region (CR) sequences. We found 36-39 distinct species with COI and 38-41 with CR. Of the species identified, 16-23 are currently listed as Endangered or Vulnerable on the IUCN Red List, an additional 2 are considered data deficient, and 7 currently listed under CITES Appendix II. Of the 2.5 tonnes of fins from this collection, we estimated 56-66% (CR or COI, respectively) come from CITES-listed species or those the IUCN considers threatened or data deficient. Most of these species occur outside of the United States EEZ, comprising a global set of species that is common in most fin surveys. The principal target shark fishery in the United States (spiny dogfish; Squalus acanthias) has no fins in our collection. Fins seen abundantly in our collection include pelagic species such as thresher, mako, oceanic whitetip, silky, blue and hammerhead sharks, as in previous samples of the shark fin supply chain. However, in addition, we see a large flood of blacktip, dusky, sandbar, and smalltail sharks that are common in shallow coastal waters. This may indicate that the global market for shark fins takes sharks from nearshore coastal zones, all over the world. Abundant species in the fin shop included globally-distributed species such as scalloped hammerheads and shortfin mako sharks, but also regionally-restricted species such as finetooth, blacknose, and Caribbean Reef sharks found only in the western Atlantic or Caribbean. Specimens identified from rare species of particular conservation concern included the wedgefish genus Rhyncobatus and the white shark. Both molecular markers performed well in identifying most fins, achieving a similar degree of taxonomic certainty. The universal primers for COI regularly amplified bacteria in wet fin samples, but the CR primers were able to return shark sequences even from these degraded samples. However, the CR primers amplified a second gene, likely a pseudogene, in some important and abundant species, and seriously underestimated some species of high conversation concern such as the thresher sharks.

Porsmoguer, S. B., Banaru, D., Boudouresque, C. F., Dekeyser, I., Viricel, A., & Merchan, M. (2015). DNA Evidence of the Consumption of Short-Beaked Common Dolphin Delphinus Delphis by the Shortfin Mako Shark *Isurus oxyrinchus*. *Marine Ecology Progress Series, 532*, 177-183 https://doi.org/10.3354/meps11327

Stomachs of shortfin mako sharks *Isurus oxyrinchus* caught in the northeastern Atlantic by Iberian longliners were analyzed. A number of juveniles, 6 out of 96 individuals with non-empty stomachs, had consumed marine mammals. The remains (skin, fat, vertebrae and flesh with the dorsal fin) were not identifiable at species level by non-genetic methods. Portions of the mitochondrial DNA control region and of the gene coding for cytochrome b were therefore sequenced. Both the short-beaked common dolphin Delphinus delphis and possibly the striped dolphin Stenella coeruleoalba were identified. Shortfin makos are able to consume marine mammals almost as large as themselves. Well-preserved D. delphis were juveniles.

Schrey, A. W., & Heist, E. J. (2002). Microsatellite Markers for the Shortfin Mako and Cross-Species Amplification in Lamniformes. *Conservation Genetics, 3*(4), 459-461 https://doi.org/10.1023/A:1020583609967

The shortfin mako, *Isurus oxyrinchus*, is a large pelagic shark (Compagno 1984) that is harvested in commercial and recreational fisheries (NMFS 2001). A restriction fragment analysis of mitochondrial DNA (Heist et al. 1996) identified the possible need for independent management of the North Atlantic shortfin mako stock. To investigate population structure for the shortfin mako using nuclear markers, we developed multiple microsatellite DNA loci.

Shivji, M., Clarke, S., Pank, M., Natanson, L., Kohler, N., & Stanhope, M. (2002). Genetic Identification of Pelagic Shark Body Parts for Conservation and Trade Monitoring. *Conservation Biology, 16*(4), 1036-1047 https://doi.org/10.1046/j.1523-1739.2002.01188.x

The conservation and management of sharks on a species-specific basis is a pressing need because of the escalating demand for shark fins and the recognition that individual shark species respond differently to exploitation. Difficulties with the identification of many commonly fished sharks and their body parts has resulted in a global dearth of catch and trade information, making reliable assessment of exploitation effects and conservation needs for individual species nearly impossible. We developed and tested a highly streamlined molecular genetic approach based on species-specific, polymerase-chain-reaction primers in an eight-primer multiplex format to discriminate simultaneously between body parts from six shark species common in worldwide pelagic fisheries. The species-specific primers are based on DNA sequence differences among species in the nuclear ribosomal internal transcribed spacer 2 locus. The primers and multiplex format accurately and sensitively distinguished samples from each of three lamnid (*Isurus oxyrinchus* , *Isurus paucus* , and *Lamna nasus*) and three carcharhinid (*Prionace glauca* , Carcharhinus obscurus , and *Carcharhinus falciformis*) species from all but one other shark species encountered in the North Atlantic fishery. Furthermore, the three lamnid primers were robust enough in their discriminatory power to be useful for species diagnosis on a global scale. Preliminary testing of dried fins from Asian and Mediterranean commercial markets suggests that our genetic approach will be useful for determining the species of origin of detached fins, thus allowing the monitoring of trade in shark fins for conservation assessment. Our approach will also facilitate detection of products from protected and other at-risk shark species and may prove useful as a model for development of the high-

throughput, genetic, species-diagnosis methods typically required in conservation and management contexts.

Taguchi, M., Kitamura, T., Shigenobu, Y., Ohkubo, M., Yanagimoto, T., Sugaya, T., . . . Yokawa, K. (2013). Development of 15 Polymorphic Microsatellite Markers for the Shortfin Mako, *Isurus oxyrinchus*, and Cross-Species Amplification in Lamniforme Sharks. *Conservation Genetics Resources, 5*(3), 675-678 https://doi.org/10.1007/s12686-013-9880-1

The shortfin mako (*Isurus oxyrinchus*, Lamniformes) is one of common sharks caught incidentally by tuna longline and drift net fisheries in the tropical and temperate waters. However, their genetic diversity and population structure for effective management remain to be elucidated with sufficient number of genetic markers. A total of fifteen novel microsatellite markers for the shortfin mako were developed using a next generation sequencing approach. All the microsatellite loci isolated were polymorphic with 2-23 alleles, with the observed and expected heterozygosities of 0.06-1.00 and 0.06-0.93, respectively. Cross-species amplification in six other lamniforme sharks was successful at thirteen out of fifteen loci isolated. The developed microsatellite markers will be useful for the population genetic analysis of lamniforme sharks including the shortfin mako.

Section IV: Population Abundance and Trends

Abascal, F. J., Quintans, M., Ramos-Cartelle, A., & Mejuto, J. (2011). Movements and Environmental Preferences of the Shortfin Mako, *Isurus oxyrinchus*, in the Southeastern Pacific Ocean. *Marine Biology, 158*(5), 1175-1184 https://doi.org/10.1007/s00227-011-1639-1

Nine individuals of shortfin mako, *Isurus oxyrinchus*, were tracked in the southeastern Pacific Ocean, off northern Chile, by means of pop-up satellite archival tags. No common pattern was observed in their trajectories, apart from a movement onshore of all the fish tracked during June-August. The average estimated rate of movement was of c. 27 km day(-1). Data were collected and processed for a total of 341 days, including 33 days for one recaptured fish specimen, allowing high-resolution archived data to be downloaded. The fish spent most of their time in the mixed layer but undertook dives down to 888 m. Ambient temperatures ranged between 4.6 and 24.1A degrees C, and the sea surface temperatures recorded ranged from 13.4 to 24.1A degrees C during the study period. No clear diel pattern in depth behavior was observed, but mean vertical distribution was deeper during the daytime. Moreover, a foraging pattern, consisting of rapid descents below the thermocline followed by slower ascents, was generally observed during daylight hours. Dissolved oxygen concentration and water temperature seem to be the main factors affecting the vertical range of the species in the area. This is the first study on electronic tagging of the shortfin mako in the southeastern Pacific Ocean and covers the longest total tracking period reported so far for this species.

Adams, G. D., Flores, D., Flores, O. G., Aarestrup, K., & Svendsen, J. C. (2016). Spatial Ecology of Blue Shark and Shortfin Mako in Southern Peru: Local Abundance, Habitat Preferences and Implications for Conservation. *Endangered Species Research, 31*, 19-32 https://doi.org/10.3354/esr00744

While global declines of pelagic shark populations have been recognized for several years, conservation efforts remain hampered by a poor understanding of their spatial distribution and ecology. Two species of conservation concern are the blue shark *Prionace glauca* and the shortfin mako shark *Isurus oxyrinchus*. To improve management of these species, this study examined their local abundance patterns, habitat preferences, and distribution in the Southeast Pacific. Catch per unit effort (CPUE) data from an artisanal fishery in Peru were used to identify geographic hot spots and model abundance estimates as a function of environmental variables, including the El Nino Southern Oscillation (ENSO). A 10 yr data series revealed declining annual landings since 2012, despite no changes in management structures. Significant aggregations of both species were found in southwestern Peruvian waters (74-76 degrees W, 17-19 degrees S), with both species-specific hot spots targeted by major fishing efforts. P. glauca CPUE increased during La Nina conditions (i.e. low water temperature anomaly), and CPUE of both species declined when water depths exceeded 1000 m. Correlations with lunar illumination and chlorophyll a were revealed in P. glauca and *I. oxyrinchus*, respectively. Modeling explained 57 to 61% of the deviance, indicating that other factors not included in the present study might account for unexplained variance in CPUE (e.g. thermocline depth, location of marine fronts, dissolved oxygen, and gear characteristics). Given the importance of the examined area to shark fisheries and the exploitation of multiple species of conservation concern, the information presented here can be used to inform management strategies designed to limit the depletion of pelagic sharks.

Au, D. W., Smith, S. E., & Show, C. (2015). New Abbreviated Calculation for Measuring Intrinsic Rebound Potential in Exploited Fish Populations - Example for Sharks. *Canadian Journal of Fisheries and Aquatic Sciences, 72*(5), 767-773 https://doi.org/10.1139/cjfas-2014-0360

Intrinsic rebound potential, the demographic measure of a fish population's productivity that sustains a given mortality, relates to a species' resiliency and can be useful for understanding and evaluating the status of exploited populations, especially those poorly monitored and of low productivity, like many shark populations. The rebound potential is derived from the Euler-Lotka equation and, with the dynamics kept simple, is easily calculated for a given total mortality, needing only a species' age at maturity and its natural mortality (M). Its value can be quickly read from an isopleth diagram, whose contour pattern shows the interdependence of these two key parameters among different life histories. How the rebound potentials change as a function of age at maturity and the full range of possible M values also shows a way to estimate a species' natural mortality bounds. Importance of the age at maturity parameter is stressed.

Babcock, E. A., & Nakano, H. (2008). Data Collection, Research, and Assessment Efforts for Pelagic Sharks by the International Commission for the Conservation of Atlantic Tunas. In *Sharks of the Open Ocean.* (pp. 472-477) https://doi.org/10.1002/9781444302516.ch37

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 (λ') and the vital parameters, maximum age (Tmax), age at maturity (Tm), annual fecundity (f/Rc)), size at birth (Lb), size at maturity (Lm), and asymptotic length (L1). Group (1) included species with slow growth rates (0.034 yr-1 < k < 0.103 yr-1) and extended longevity (26 yr < Tmax < 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 < Tmax < 26 yr), e.g., starspotted smoothhound Mustelus manazo, gray smoothhound M. californicus, etc.; Group (3) included late maturing species (Lm/L1≧ 0.75) with moderate longevity (Tmax < 29 yr), e.g., pelagic thresher *Alopias pelagicus*, sevengill shark Notorynchus cepedianus. The empirical equation for all data pooled was also developed. The λ' 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.

Babcock, E. A., & Cortes, E. (2009). Updated Bayesian Surplus Production Model Applied to Blue and Mako Shark Catch, Cpue and Effort Data. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas, 64*(5), 1568-1577 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/SCRS/SCRS-08-135_Babcock_&_Cortes_REV.pdf

The Bayesian Surplus Production (BSP) model runs from the 2004 assessment were updated for both blue and shortfin mako sharks using newly available effort and CPUE data. Updated informative priors for the rate of population increase (r) were used, consistent with the approach used at the 2004 ICCAT assessment. For blue and mako sharks in the Atlantic, catch data are incomplete for most of the history of the fishery. Therefore, we developed a variation on the BSP model that can be fitted to a series of longline effort data rather than catch in the early years of the fishery. The model was used to explore potential contradictions in the available abundance index data, and to explore the implications of alternative assumptions about catch and/or effort history. Both the model runs using the effort data and those using the estimated catches from the 2004 assessment gave similar results.

Babcock, E. A., & Cortes, E. (2010). Bayesian Surplus Production Model Applied to Porbeagle Catch, Cpue and Effort Data. . *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas, 65*(6), 2051-2057 Retrieved from https://iccat.int/en/pubs_CVSP.html

The Bayesian Surplus Production (BSP) model that was used in the ICCAT assessments of blue and shortfin mako shark in 2004 and 2008 was applied to northwest Atlantic porbeagle. An informative prior was developed for the rate of population increase (r) based on demographic data. Catch and catch per unit effort data were taken from the literature. We compared the results of the surplus production model to the age structured stock assessment results for the northwest Atlantic population. Catch and CPUE data were not available from the literature for the northeast and southern Atlantic populations. To use the BSP model for this population, it will be necessary to develop at least one CPUE index of abundance for each population, as well as a time series of catches. If catch data are not available for the entire history of the fishery, the BSP model can be fitted to a series of longline effort data rather than catch in the early years of the fishery.

Barreto, R. R., de Farias, W. K., Andrade, H., Santana, F. M., & Lessa, R. (2016). Age, Growth and Spatial Distribution of the Life Stages of the Shortfin Mako, *Isurus oxyrinchus* (Rafinesque, 1810) Caught in the Western and Central Atlantic. *PLOS ONE, 11*(4), e0153062 https://doi.org/10.1371/journal.pone.0153062

The shortfin mako (*Isurus oxyrinchus*) is a highly migratory pelagic shark that preferentially inhabits oceanic regions in practically all oceans. The wide distribution range of this species renders it susceptible to coastal and oceanic fishing operations. The International Union for Conservation of Nature (IUCN) and the International Commission for the Conservation of Atlantic Tunas (ICCAT) consider this species to be highly vulnerable, especially due to its biological parameters, which are different from those of other sharks that occupy the same niche (e.g., *Prionace glauca*). Consequently, considerable declines in abundance have been detected over various parts of its range, most of which are linked to oceanic longline fishing. The species has conflicting life history parameters in studies conducted in the last 30 years, especially with regard to age and growth. The main discrepancies regard the interpretation of the periodicity of the deposition of band pairs (BPs) on vertebrae and the possibility of ontogenetic variations in growth. Shortfin mako sharks (n = 1325) were sampled by onboard observers of the Brazilian chartered pelagic longline fleet based in northeast Brazil from 2005 to 2011. Lengths were 79 to 250 and 73 to 296 cm (fork length, FL) for males and females, respectively, with a statistically significant difference in size between sexes and differences in the proportion of individuals in each size class. The onboard observers collected a subsample of vertebrae (n = 467), only 234 of which were suitable for analyses. Reliability between readings was satisfactory. However, it was not possible to validate periodicity in the formation of age bands in the sample. Thus, the von Bertalanffy growth function was used to calculate growth rates for the species through the interpretation of BPs in different scenarios: one BP per year (s1), two BPs per year (s2) and two BPs per year until five years of life (s3). Growth parameters varied for both females (Linf = 309.7[s3] to 441.6[s1]; k = 0.04[s1] to 0.13[s3]; t0 = -7.08[s1] and -3.27[s3]) and males (Linf = 291.5[s3] to 340.2[s1]; k = 0.04[s1] to 0.13[s3]; t0 = -7.08[s1] and -3.27[s3]). To advance the understanding of the use of habitat, the first analysis of the spatial distribution of the life stages of the shortfin mako sharks caught by commercial longline fishing operations in the South Atlantic was performed. The findings indicate that the portion of the population exploited by the fleets is predominantly juvenile and future actions should take the following issues into account: improvements in the efficiency of data collection procedures, the reestablishment of the onboard observer program, emergency investments in studies that can contribute to a better understanding of habitat use and life history theory.

Besnard, L., Le Croizier, G., Galván-Magaña, F., Point, D., Kraffe, E., Ketchum, J., . . . Schaal, G. (2021). Foraging Depth Depicts Resource Partitioning and Contamination Level in a Pelagic Shark Assemblage: Insights from Mercury Stable Isotopes. *Environmental Pollution, 283*, 117066 https://doi.org/10.1016/j.envpol.2021.117066

The decline of shark populations in the world ocean is affecting ecosystem structure and function in an unpredictable way and new ecological information is today needed to better understand the role of sharks in their habitats. In particular, the characterization of foraging patterns is crucial to understand and foresee the evolution of dynamics between sharks and their prey. Many shark species use the mesopelagic area as a major foraging ground but the degree to which different pelagic sharks rely on this habitat remains overlooked. In order to depict the vertical dimension of their trophic ecology, we used mercury stable isotopes in the muscle of three pelagic shark species (the blue shark *Prionace glauca*, the shortfin mako shark *Isurus oxyrinchus* and the smooth hammerhead shark *Sphyrna zygaena*)

from the northeastern Pacific region. The Δ199Hg values, ranging from 1.40 to 2.13‰ in sharks, suggested a diet mostly based on mesopelagic prey in oceanic habitats. We additionally used carbon and nitrogen stable isotopes (δ13C, δ15N) alone or in combination with Δ199Hg values, to assess resource partitioning between the three shark species. Adding Δ199Hg resulted in a decrease in trophic overlap estimates compared to those based on δ13C/δ15N alone, demonstrating that multi-isotope modeling is needed for accurate trophic description of the three species. Mainly, it reveals that they forage at different average depths and that resource partitioning is mostly expressed through the vertical dimension within pelagic shark assemblages. Concomitantly, muscle total mercury concentration (THg) differed between species and increased with feeding depth. Overall, this study highlights the key role of the mesopelagic zone for shark species foraging among important depth gradients and reports new ecological information on trophic competition using mercury isotopes. It also suggests that foraging depth may play a pivotal role in the differences between muscle THg from co-occurring high trophic level shark species.

Bilecenoglu, M., Alfaya, J. E. F., Azzurr, E., Baldacconi, R., Boyaci, Y. O., Circosta, V., . . . Zava, B. (2013). New Mediterranean Marine Biodiversity Records (December, 2013). *Mediterranean Marine Science, 14*(2), 463-480 https://doi.org/10.12681/mms.676

Based on recent biodiversity studies carried out in different parts of the Mediterranean, the following 19 species are included as new records on the floral or faunal lists of the relevant ecosystems: the green algae *Penicillus capitatus* (Maltese waters); the nemertean *Amphiporus allucens* (Iberian Peninsula, Spain); the salp *Salpa maxima* (Syria); the opistobranchs *Felimida britoi* and *Berghia coerulescens* (Aegean Sea, Greece); the dusky shark *Carcharhinus obscurus* (central-west Mediterranean and Ionian Sea, Italy); Randall's threadfin bream *Nemipterus randalli*, the broadbanded cardinalfish *Apogon fasciatus* and the goby *Gobius Kolombatovici* (Aegean Sea, Turkey); the reticulated leatherjack *Stephanolepis diaspros* and the halacarid *Agaue chevreuxi* (Sea of Marmara, Turkey); the slimy liagora *Ganonema farinosum*, the yellowstripe barracuda *Sphyraena chrysotaenia*, the rayed pearl oyster *Pinctada imbricata radiata* and the Persian conch *Conomurex persicus* (south-eastern Kriti, Greece); the blenny *Microlipophrys dalmatinus* and the bastard grunt *Pomadasys incisus* (Ionian Sea, Italy); the brown shrimp *Farfantepenaeus aztecus* (north-eastern Levant, Turkey); the blue-crab *Callinectes sapidus* (Corfu, Ionian Sea, Greece). In addition, the findings of the following rare species improve currently available biogeographical knowledge: the oceanic pufferfish *Lagocephalus lagocephalus* (Malta); the yellow sea chub *Kyphosus incisor* (Almunecar coast of Spain); the basking shark *Cetorhinus maximus* and the shortfin mako *Isurus oxyrinchus* (north-eastern Levant, Turkey).

Braccini, M., Brooks, E. N., Wise, B., & McAuley, R. (2015). Displaying Uncertainty in the Biological Reference Points of Sharks. *Ocean & Coastal Management, 116*, 143-149 https://doi.org/10.1016/j.ocecoaman.2015.07.014

Variability in life-history traits influences biological reference points (BRP). For data-poor species such as sharks, BRP have commonly been set at arbitrary values with little consideration of life-history variability. The temperate shark fisheries of Western Australia were used as a case study to develop species-specific limit, threshold and target BRP that consider life history uncertainty and population dynamics. Shark species with higher biological productivity had lower biomass BRP and higher fishing mortality BRP (F-BRP) than less productive species. The interplay of gear selectivity and variability in life history traits influenced BRP uncertainty, particularly for F-BRP. Traditionally, stock status is determined

by comparing a stock-performance indicator (SPI) to a BRP point estimate based on a set probability of SPI exceeding the point BRP. We proposed an alternative approach where we considered distributions for both SPI and BRP and compared the proportion of overlap between those distributions. In practice, we consider this an improvement to characterizing both uncertainties and an easier-to-grasp concept than a probability of exceeding a point estimate.

Braccini, M., Taylor, S., Bruce, B., & McAuley, R. (2017). Modelling the Population Trajectory of West Australian White Sharks. *Ecological Modelling, 360*, 363-377 https://doi.org/10.1016/j.ecolmodel.2017.07.024

White sharks (*Carcharodon carcharias*) are globally distributed, protected in several countries, including Australia, and potentially dangerous to humans. Following a recent spate of fatal white shark attacks, the Government of Western Australia introduced a range of initiatives to mitigate shark hazards. An increasing trend in shark attacks over the last 20 years has been commonly perceived to be the result of an increase in population abundance since the species' protection in Australian waters in 1997. We modelled potential population productivity and trajectories using different scenarios of life-history strategies, unexploited population sizes, reconstructed fishery catches and post-capture mortality. Under zero fishing mortality, the potential annual increase in population abundance varied from 2 to 6% per year, depending upon the assumed life history strategy. Depending upon model inputs there was a wide range of potential declines in abundance since 1938/39 and significant differences in the potential population trajectories since protection. However, no scenario (n = 120) resulted in a total population increase of >31% since protection, with most scenarios showing population increase of 10% or less. We present a method for exploring the effects of alternative hypotheses about key population parameters when data are scarce and when scientific advice is required for guiding decision making and informing public debate.

Buencuerpo, V., Rios, S., & Moron, J. (1998). Pelagic Sharks Associated with the Swordfish, *Xiphias gladius*, Fishery in the Eastern North Atlantic Ocean and the Strait of Gibraltar. *Fishery Bulletin, 96*(4), 667-685 Retrieved from https://spo.nmfs.noaa.gov/content/pelagic-sharks-associated-swordfish-xiphias-gladius-fishery-eastern-north-atlantic-ocean-and

We report on 175 landings from 106 longline and 69 gillnet boats operating in the eastern North Atlantic Ocean and Mediterranean Sea, July 1991 to July 1992. Information on the catch and biology of five shark species (*Isurus oxyrinchus*, *Prionace glauca*, *Alopias superciliosus*, *Alopias vulpinus*, and *Sphyrna zygaena*) is analyzed and contrasted with swordfish (*Xiphias gladius*) landings. A total of 51,205 fish were sampled, of which 40,198 were sharks, 9,990 swordfish, and the rest other bony fish. Spatial, temporal, and gear analyses were performed to show the importance of shark bycatch in longline and gillnet fisheries operating from the south of Spain. We present information on population structures of the shark species, along with hypotheses about shortfin mako movements as suggested by landing data.

Bustamante, C., & Bennett, M. B. (2013). Insights into the Reproductive Biology and Fisheries of Two Commercially Exploited Species, Shortfin Mako (*Isurus oxyrinchus*) and Blue Shark (*Prionace glauca*), in the South-East Pacific Ocean. *Fisheries Research, 143*, 174-183 https://doi.org/10.1016/j.fishres.2013.02.007

In 2005 and 2010,1241 *Isurus oxyrinchus* and 1153 *Prionace glauca* were collected from 178 longline sets in a ship-board observer programme in coastal waters off Caldera, Chile (27 degrees S). Catch composition was significantly biased towards *I. oxyrinchus* in 2005, but both species were caught in the same proportion in 2010. The sex ratio for L oxyrinchus and for P. glauca did not differ significantly from unity within or between years. Sharks matured (L-50) at a total length of 190.3 cm for male and 199.2 cm for female for P. glauca, and 180.2 cm for male *I. oxyrinchus*. Size-at-maturity for female *I. oxyrinchus* was not determined due to the near absence of mature specimens examined. Generalised additive models (GAMs) were used to examine catch per unit effort (CPUE) in relation to sea surface temperature, wind speed, time of day, hook depth and soak time. The GAMs revealed a significant effect of depth on P. glauca CPUE, and depth and wind speed for *I. oxyrinchus* CPUE. The predominance of small, immature sharks caught in the coastal, artisanal fishery indicates that both species may use the area as a pupping, and possibly a nursery zone during spring and summer. National data on catch composition and annual landings provide evidence of an increasing trend to land P. eauca, possibly to satisfy the international shark fin trade. Conservation measures, such as the introduction of a minimum capture size for sharks to protect the recruitment into the population, conservative fishing quotas and delimitation of fishing areas are necessary to ensure the sustainability of both species in the region.

Byrne, M. E., Cortes, E., Vaudo, J. J., Harvey, G. C. M., Sampson, M., Wetherbee, B. M., & Shivji, M. (2017). Satellite Telemetry Reveals Higher Fishing Mortality Rates Than Previously Estimated, Suggesting Overfishing of an Apex Marine Predator. *Proceedings of the Royal Society B-Biological Sciences, 284*(1860) https://doi.org/10.1098/rspb.2017.0658

Overfishing is a primary cause of population declines for many shark species of conservation concern. However, means of obtaining information on fishery interactions and mortality, necessary for the development of successful conservation strategies, are often fisheries-dependent and of questionable quality for many species of commercially exploited pelagic sharks. We used satellite telemetry as a fisheries-independent tool to document fisheries interactions, and quantify fishing mortality of the highly migratory shortfin mako shark (*Isurus oxyrinchus*) in the western North Atlantic Ocean. Forty satellite-tagged shortfin mako sharks tracked over 3 years entered the Exclusive Economic Zones of 19 countries and were harvested in fisheries of five countries, with 30% of tagged sharks harvested. Our tagging-derived estimates of instantaneous fishing mortality rates (F = 0.19-0.56) were 10-fold higher than previous estimates from fisheries-dependent data (approx. 0.015-0.024), suggesting data used in stock assessments may considerably underestimate fishing mortality. Additionally, our estimates of F were greater than those associated with maximum sustainable yield, suggesting a state of overfishing. This information has direct application to evaluations of stock status and for effective management of populations, and thus satellite tagging studies have potential to provide more accurate estimates of fishing mortality and survival than traditional fisheries-dependent methodology.

Cailliet, G. M. (2015). Perspectives on Elasmobranch Life-History Studies: A Focus on Age Validation and Relevance to Fishery Management. *Journal of Fish Biology, 87*(6), 1271-1292 https://doi.org/10.1111/jfb.12829

Life-history (age, growth, age validation, reproduction and demography) studies of elasmobranchs date back to the middle of the last century with major early contributions made by British fishery scientists. As predicted by Holden in the early 1970s, many sharks and rays can be vulnerable to fishery mortality because they grow slowly, mature late in life, reproduce infrequently, have relatively low fecundities

and can have relatively long life spans. As has now been found, however, not all species exhibit these traits. Also, ageing structures (neural arches and caudal thorns), other than vertebrae and spines, have since been evaluated. Various methods for validating age and growth estimates have been developed and tested on numerous species of elasmobranchs. These include tag-recapture analyses, oxytetracycline injections, centrum or spine edge and marginal increment analyses, and bomb radiocarbon dating of calcified structures. Application of these techniques has sometimes not only validated relatively slow growth and long life span estimates, but also has produced other results. A brief historical perspective on the applications and limitations of these techniques for elasmobranchs is provided, along with a discussion of selected species for which these techniques worked well, did not work at all or have produced variable and conflicting results. Because many fishery management techniques utilize age or stage-specific information, often through demographic analyses, accurate information on the life histories of fished populations, especially age validation, is extremely important for the fishery management of these cartilaginous fishes.

Campana, S. E., Marks, L., & Joyce, W. (2005). The Biology and Fishery of Shortfin Mako Sharks (*Isurus oxyrinchus*) in Atlantic Canadian Waters. *Fisheries Research, 73*(3), 341-352 https://doi.org/10.1016/j.fishres.2005.01.009

Shortfin mako sharks are a high-value bycatch of pelagic longline fisheries off the eastern coast of Canada. Tagging studies indicate that they are highly migratory, seasonal residents of Canadian waters, representing the northern extension of a North Atlantic-wide population centred at more southerly latitudes. Annual catches in Canadian waters average 60-80 rut per year, which represents but a small part of that estimated for the population as a whole. New ageing results indicate that the species grows more slowly than was reported previously, thus making the population less productive and more susceptible to overexploitation than has been reported. Two indices of population abundance did not provide a definitive view of mako shark population status. A standardized catch rate index from the commercial large pelagic fishery suggested stable abundance since 1988. However, the analysis did not have the statistical power to detect anything less than a severe decline. In contrast, the median size of mako sharks in the commercial catch has declined since 1998, suggesting a loss of larger sharks. These results are broadly consistent with a previous report of population decline, although it appears unlikely that current exploitation rates in Canada are having an appreciable impact on the population.

Carreon-Zapiain, M. T., Favela-Lara, S., Gonzalez-Perez, J. O., Tavares, R., Leija-Tristan, A., Mercado-Hernandez, R., & Compean-Jimenez, G. A. (2018). Size, Age, and Spatial-Temporal Distribution of Shortfin Mako in the Mexican Pacific Ocean. *Marine and Coastal Fisheries, 10*(4), 402-410 https://doi.org/10.1002/mcf2.10029

Basic population parameters such as age, size, and distribution have been poorly evaluated for the Shortfin Mako *Isurus oxyrinchus* in the Mexican Pacific Ocean. According to data collected by scientific observers on board medium-size fishing vessels during the period of 2006-2013, size as TL was obtained for 5,740 individual sharks. The range of TL was 70-362 cm for females and 71-296 cm for males. Weight (W), measured randomly from 1,409 individuals, ranged from 2 to 90 kg for females and from 2 to 80 kg for males. The weight-to-TL ratio was best fitted by the equation W = 4 x 10(-5)(TL)(2.59) (r(2) = 0.6532). No sex-specific difference was found in the weight-to-TL relationship between males and females, nor in W or TL separately. By using the inverse von Bertalanffy equation and parameters described by other authors for the same study area, we determined the age range for individuals captured on the basis of

their TL. The age ranged from 0 to 39 years in females and from 0 to 21 years in males. Using a logistic model, the mean length at sexual maturity was obtained for 2,532 males (TL = 190 cm). The quarterly distribution of young of the year and 1-year-old juveniles showed that there is a tendency for these sharks to move northward as sea surface temperature increases. Our findings shed new light on how Shortfin Mako juveniles use a habitat that has been proposed by other authors as a nursery area for this species, information that is valuable for the sustainability of the Mexican Pacific fisheries.

Carvalho, F., Lee, H. H., Piner, K. R., Kapur, M., & Clarke, S. C. (2018). Can the Status of Pelagic Shark Populations Be Determined Using Simple Fishery Indicators? *Biological Conservation, 228*, 195-204 https://doi.org/10.1016/j.biocon.2018.09.034

Calls to develop alternative methods of assessing the population status of pelagic shark populations have increased substantially in recent years. An interim solution has been the development of more subjective evaluation of data series (indicator-based analysis) rather than predictions from complex stock assessment models. This paper examines the reliability of indicators for predicting population status (i.e. whether it has been overfished) and the fishing pressure (i.e. whether overfishing is occurring) of large pelagic sharks, based on these fishery indicator trends alone. We simulate a variety of large pelagic shark populations under different exploitation scenarios using life history parameters, and measurable fishery indicators information (catch-per-unit of effort - CPUE; and average length - AL). Our simulation results, designed to be generalized (via sampling of realistic distributions) but based loosely on the shortfin mako shark, showed that the reliability of fishery indicators for establishing population status is dependent upon the length of the time series analyzed. These caveats are critical to the proper evaluation of population trajectories that underlie the most important conservation decisions being made for sharks today.

Casey, J. G., & Kohler, N. E. (1992). Tagging Studies on the Shortfin Mako Shark (*Isurus oxyrinchus*) in the Western North Atlantic. *Marine and Freshwater Research, 43*(1), 45-60 https://doi.org/10.1071/mf9920045

Results of an ongoing Cooperative Shark Tagging Program conducted by the National Marine Fisheries Service (USA) are described. In all, 2459 shortfin mako sharks (*Isurus oxyrinchus*) were tagged off the Atlantic coast of North America and in the Gulf of Mexico in the 28-year period between 1962 and 1989. The sharks were tagged by volunteer fishers, scientists aboard research vessels, and US Foreign Fisheries Observers on foreign vessels fishing in US waters. Altogether, 231 recaptures (9.4% of releases) of these tagged sharks have been reported by fishers from 16 countries. The maximum time at liberty is 8.2 years, and the maximum straight-line distance between tag and recapture localities is 2452 nautical miles. One tag was recovered from the European side of the Mid-Atlantic Ridge. Mako shark distribution and migratory patterns in relation to water temperature are discussed for the western North Atlantic.

Celona, A. (2004). Two Large Shortfin Makos, *Isurus oxyrinchus*, Rafinesque, 1809, Caught Off Sicily, Western Ionian Sea. *Annales. Anali za istrske in mediteranske studije. (Series historia naturalis), 14*(1), 35-42 Retrieved from http://www.zrs.upr.si/media/uploads/files/celona%20et%20al(1).pdf

The authors report on two large shortfin makos *Isurus oxyrinchus* captured off Sicily, Western Ionian Sea (Central Mediterranean Sea). A female shortfin mako was caught on 26 July 2003 off Scaletta Zanclea. The specimen's total length of 390 cm was estimated on the basis of a photograph and measurements of the pectoral and first dorsal fins. Another 370 cm female shortfin mako was captured between Portopalo di Capo Passero and Marzamemi and transported to the fish market in Milan, Italy, on 22 June 2004. The two specimens reported in this work are the largest ever recorded in Sicilian waters, and among the largest recorded from the entire Mediterranean Sea.

Chang, J.-H., & Liu, K.-M. (2009). Stock Assessment of the Shortfin Mako Shark (*Isurus oxyrinchus*) in the Northwest Pacific Ocean Using Per Recruit and Virtual Population Analyses. *Fisheries Research, 98*(1), 92-101 https://doi.org/10.1016/j.fishres.2009.04.005

The shortfin mako shark (*Isurus oxyrinchus*) is a cosmopolitan species abundant in the Northwest Pacific. Some aspects of its biological information have been well documented yet its population dynamics is poorly known. The objective of this study is to assess the population status of the shortfin mako in the Northwest Pacific. The whole weights of 68,943 female and 64,338 male shortfin mako landed at Nanfangao and Chengkung fish markets, eastern Taiwan from 1990 to 2004 were converted to total length and the age for each individual was estimated based on the sex-specific von Bertalanffy growth equation. Total mortality obtained with length-converted catch curves ranged from 0.175yr−1 to 0.272yr−1 for females and from 0.196yr−1 to 0.286yr−1 for males. Natural mortality estimated from Peterson and Wroblewski's equation were 0.077–0.244yr−1 for females and 0.091–0.203yr−1 for males. Based on virtual population analysis, the highest fishing mortality occurred in ages 6–10 years for females and 7–12 years for males. Increases of fishing mortality in ages 3–5 years for females and 3–6 years for males since 1996 indicated that the young shortfin mako experienced higher fishing pressure in recent years. Both deterministic and stochastic simulations showed that annual spawning potential ratio (SPR) of shortfin mako was lower than the biological reference point (BRP) of SPR 35% and had a decreasing trend since 2000. Current fishing mortality (0.066yr−1) was greater than the BRP of F30% (0.052yr−1), F35% (0.045yr−1), F40% (0.04yr−1) and F0.1 (0.063yr−1) suggesting that this stock might have been overexploited. Therefore, to ensure sustainable utilization, a management measure of 32% reduction of current fishing effort was suggested for the shortfin mako stock in the Northwest Pacific.

Clarke, S., Nakano, H., & Takeuchi, Y. (2004). Comparison of Japanese Logbook and Observer Data for Shortfin Mako (*Isurus oxyrinchus*) in the Atlantic Ocean Using Bayesian Glm Methods. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas, 58*(3), 1150-1156 Retrieved from https://www.iccat.int/Documents/CVSP/CV058_2005/n_3/CV058031150.pdf

A method for filtering logbook data to obtain estimates of catch per unit effort for shortfin mako shark (*Isurus oxyrinchus*) was tested through comparison to observer data in the Japanese longline fishery for the Atlantic Ocean from 1994-2002. Both logbook and observer data sets were modeled using a Bayesian Generalized Linear Model framework to produce probability intervals for comparison. A filter based on reporting rates of 11-30% was shown to provide results more compatible with observer data than a lower filter of 0-20% reporting rate. This information can be applied when selecting a reporting rate filter to apply to non species-specific shark catch data in logbooks prior to 1994 when producing estimates for shortfin mako sharks. High reporting rate filters (>70% and >80%) achieved similar or

better fits to observer data and indicate that imputation methods for shortfin mako shark catch and CPUE series estimation may prove useful.

Coelho, R., Macías, D., Ortiz de Urbina, J., Martins, A., Monteiro, C., Lino, P. G., . . . Santos, M. N. (2020). Local Indicators for Global Species: Pelagic Sharks in the Tropical Northeast Atlantic, Cabo Verde Islands Region. *Ecological Indicators, 110*, 105942 https://doi.org/10.1016/j.ecolind.2019.105942

Pelagic sharks are an important bycatch in pelagic fisheries, especially for drifting longlines targeting swordfish. In the Cabo Verde Archipelago (tropical NE Atlantic), pelagic shark catches can reach a significant proportion of the total catches. Due to the increased concern on the status of pelagic shark species, this study was developed to enhance the current knowledge of those sharks in the Cabo Verde region in comparison to the adjacent areas, especially associated with European Union (EU) pelagic longline fishing activity. Stock status indicators for the two main species, blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*), were developed, based on fisheries data from logbooks and onboard scientific observers, including analysis of size frequency distributions and standardized catch-per-unit-of-effort (CPUE) indexes over time. The standardized CPUEs have been stable or increasing for both species in the past 10 years, indicating no signs of local depletion. In terms of sizes, the blue shark catch is composed mainly of adults, which can be a sign of a stable population. On the contrary, the catch of shortfin mako is composed mainly of juveniles, which in conjunction of a decrease of mean size might be a cause of concern, highlighting possible overfishing on the species in the region. Thirty satellite tags, 25 archival miniPATs and 5 SPOT GPS, were deployed in the Cabo Verde Exclusive Economic Zone (EEZ), showing that those species are highly mobile. The biomass and size distributions were modeled with spatial and seasonal models (GAMs) identifying locations where juveniles are predominantly concentrated and that should be prioritized for conservation. This work presents new information on the status of pelagic sharks in the Cabo Verde region in the context of those highly migratory species, and can now be used to promote more sustainable fisheries in the region.

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, 95*(4), 1072-1085 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.

Corrigan, S., Lowther, A. D., Beheregaray, L. B., Bruce, B. D., Cliff, G., Duffy, C. A., . . . Rogers, P. J. (2018). Population Connectivity of the Highly Migratory Shortfin Mako (*Isurus oxyrinchus* Rafinesque 1810) and Implications for Management in the Southern Hemisphere. *Frontiers in Ecology and Evolution, 6* https://doi.org/10.3389/fevo.2018.00187

In this paper we combine analyses of satellite telemetry and molecular data to investigate spatial connectivity and genetic structure among populations of shortfin mako (*Isurus oxyrinchus*) in and around Australian waters, where this species is taken in recreational and commercial fisheries. Mitochondrial DNA data suggest matrilineal substructure across hemispheres, while nuclear DNA data indicate shortfin mako may constitute a globally panmictic population. There was generally high genetic connectivity within Australian waters. Assessing genetic connectivity across the Indian Ocean basin, as well as the extent that shortfin mako exhibit sex biases in dispersal patterns would benefit from future improved sampling of adult size classes, particularly of individuals from the eastern Indian Ocean. Telemetry data indicated that Australasian mako are indeed highly migratory and frequently make long-distance movements. However, individuals also exhibit fidelity to relatively small geographic areas for extended periods. Together these patterns suggest that shortfin mako populations may be genetically homogenous across large geographical areas as a consequence of few reproductively active migrants, although spatial partitioning exists. Given that connectivity appears to occur at different scales, management at both the national and regional levels seems most appropriate.

Corro-Espinosa, D., Marquez-Farias, J. F., & Muhlia-Melo, A. (2011). Size at Maturity of the Pacific Sharpnose Shark Rhizoprionodon Longurio in the Gulf of California, Mexico. *Ciencias Marinas, 37*(2), 201-214 https://doi.org/10.7773/cm.v37i2.1934

We report on the proportion of maturity stages as a function of size of the Pacific sharpnose shark Rhizoprionodon longurio. Based on the development of internal and external organs, males and females were classified as immature or mature. A logistic model was fitted to develop a maturity curve to estimate the length at which 50% of the individuals are mature (L-50%). This species has an annual reproductive cycle and its birthing season is from April to July, with June as the main month. For males, L-50% = 100.61 cm total length (TL) and Phi = 2.57, and for females, L-50% = 92.9 cm TL and Phi = 1.08. For pregnant females, L-50% = 106.4 cm TL and Phi = 6.11. The maturity curves obtained in the present study can be used in demographic studies to produce more accurate forecasts of the population reproductive rate and thus develop fishery management measures for this species.

Domingues, R. R., Mastrochirico-Filho, V. A., Mendes, N. J., Hashimoto, D. T., Coelho, R., da Cruz, V. P., . . . Mendonça, F. F. (2020). Comparative Eye and Liver Differentially Expressed Genes Reveal Monochromatic Vision and Cancer Resistance in the Shortfin Mako Shark (*Isurus oxyrinchus*). *Genomics, 112*(6), 4817-4826 https://doi.org/10.1016/j.ygeno.2020.08.037

The shortfin mako, *Isurus oxyrinchus* is an oceanic pelagic shark found worldwide in tropical and subtropical waters. However, the understanding of its biology at molecular level is still incipient. We sequenced the messenger RNA isolated from eye and liver tissues. De novo transcriptome yielded a total of 705,940 transcripts. A total of 3774 genes were differentially expressed (DEGs), with 1612 in the eye and 2162 in the liver. Most DEGs in the eye were related to structural and signaling functions, including nonocular and ocular opsin genes, whereas nine out of ten most overexpressed genes in the liver were related to tumor suppression, wound healing, and human diseases. Furthermore, DEGs findings provide insights on the monochromatic shark vision and a repertory of cancer-related genes, which may be insightful to elucidate shark resistance to cancer. Therefore, our results provide valuable sequence resources for future functional and population studies.

Duarte, H. O., Droguet, E. L., & Moura, M. C. (2018). Quantitative Ecological Risk Assessment of Shortfin Mako Shark (*Isurus oxyrinchus*): Proposed Model and Application Example. *Applied Ecology and Environmental Research, 16*(3), 3691-3709 https://doi.org/10.15666/aeer/1603_36913709

Most of the world's catches of sharks are incidentally taken by tuna fishing gear, constituting bycatches that increase the extinction risk of several species of shark. This not only alters ecosystem functions by removing top predators, but may also hinder the industry production itself due to cutoff measures set by authorities. This paper focuses on the female population abundance of a very important bycatch species, the shortfin mako shark (*Isurus oxyrinchus*), and proposes a stochastic model for quantitative risk assessment under varying harvest regimes and control measures. The proposed model can be applied to any shortfin mako shark population by changing initial conditions and harvest parameters. The flexibility of the model makes it practicable to simulate hundreds of scenarios, analyse and compare the most relevant results such as the risk of extinction caused by a given harvest regime, median time to extinction, expected minimum biomass, risk of low harvest, and risk reduction caused by control measure; these outcomes are useful for rational decisions under uncertainty. We present an application example as a means to demonstrate how the proposed model can be used to drive management decisions for sustainable tuna harvest.

Francis, M. P. (2006). Morphometric Minefields—Towards a Measurement Standard for Chondrichthyan Fishes. *Environmental Biology of Fishes, 77*(3-4), 407-421 https://doi.org/10.1007/s10641-006-9109-1

Size measurements are crucial for studies on the growth, maturation, maximum size, and population structure of cartilaginous fishes. However, researchers use a variety of measurement techniques even when working on the same species. Accurate comparison of results among studies is only possible if the measurement technique used is adequately defined and, if different techniques are used, a conversion equation can be derived. These conditions have not always been met, leading to invalid comparisons and incorrect conclusions. This paper reviews methods used for measuring chondrichthyans, and summarises the variety of constraints that influence the choice of a measurement technique. Estimates of the variability present in some measurement techniques are derived for shortfin mako shark, *Isurus oxyrinchus*, porbeagle shark, *Lamna nasus*, blue shark, *Prionace glauca*, Antarctic thorny skate, Amblyraja georgiana, and Pacific electric ray, Torpedo californica. Total length measured with the tail in the natural position (sharks) and disc widths (batoids) have higher variability than other methods, and are not recommended. Instead, the longest longitudinal axis should be measured where possible and practical; i.e., flexed total length for sharks, total length for batoids (excluding suborder Myliobatoidei),

pelvic length for batoids of the suborder Myliobatoidei, and chimaera length (snout to posterior end of supracaudal fin) for chimaeroids (except for Callorhinchus, for which fork length should be measured from the anterior edge of the snout protuberance). Straight-line measurements are preferred to measurements over the curve of the body. Importantly, measurement methods must be clearly defined, giving information on the anterior reference point, the posterior reference point, and how the measurement was made between these two. Measurements using at least two different methods are recommended on at least a subsample of the fish in order to develop conversion regression relationships.

Francis, M. P., & Duffy, C. (2005). Length at Maturity in Three Pelagic Sharks (*Lamna nasus*, *Isurus oxyrinchus*, and *Prionace glauca*) from New Zealand. *Fishery Bulletin, 103*(3), 489-500 Retrieved from https://spo.nmfs.noaa.gov/content/length-maturity-three-pelagic-sharks-lamna-nasus-isurus-oxyrinchus-and-prionace-glauca-new

Reproductive data collected from porbeagle, shortfin mako, and blue sharks caught around New Zealand were used to estimate the median length at maturity. Data on clasper development, presence or absence of spermatophores or spermatozeugmata, uterus width, and pregnancy were collected by observers aboard tuna longline vessels. Direct maturity estimates were made for smaller numbers of sharks sampled at recreational fishing competitions. Some data sets were sparse, particularly over the vital maturation length range, but the availability of multiple indicators of maturity made it possible to develop estimates for both sexes of all three species. Porbeagle shark males matured at 140-150 cm fork length and females at about 170-180 cm. New Zealand porbeagles therefore mature at shorter lengths than they do in the North Atlantic Ocean. Shortfin mako males matured at 180-185 cm and females at 275-285 cm. Blue shark males matured at about 190-195 cm and females at 170-190 cm; however these estimates were hampered by small sample sizes, difficulty obtaining representative samples from a population segregated by sex and maturity stage, and maturation that occurred over a wide length range. It is not yet clear whether regional differences in median maturity exist for shortfin mako and blue sharks.

Francis, M. P., Griggs, L. H., & Baird, S. J. (2001). Pelagic Shark Bycatch in the New Zealand Tuna Longline Fishery. *Marine and Freshwater Research, 52*(2), 165-178 https://doi.org/10.1071/mf00086

Tuna longline effort declined from 23-26 million hooks per year in 1979-82 to 2-4 million hooks per year in 1995-98. Scientific observer coverage averaged 7.5% since 1988-89, but increased in 1992-93 (mean 23%). Observed catch per unit effort (CPUE) and the numbers of hooks set were used to estimate shark catches. Between 1988-89 and 1997-98, about 450 000 blue sharks (*Prionace glauca*), 65 000 porbeagles (*Lamna nasus*) and 25 000 shortfin makos (*Isurus oxyrinchus*) were caught. In 1997-98, about 45 000 blue sharks, 4000 porbeagles and 3000 makos were caught. Corresponding weight estimates were 1400 t, 150 t and 200 t. CPUE varied between foreign and domestic vessels, between north and south regions and among years, but there were no consistent temporal trends. Most males and females were immature, and most sharks were alive when recovered. Most sharks were processed, but usually only the fins were retained. The New Zealand tuna longline fishery is probably not seriously affecting pelagic shark stocks, but adequate assessment is not currently feasible. Accurate monitoring of Pacific Ocean catches is an important first step towards ensuring sustainability of their populations.

French, R. P., Lyle, J., Tracey, S., Currie, S., & Semmens, J. M. (2015). High Survivorship after Catch-and-Release Fishing Suggests Physiological Resilience in the Endothermic Shortfin Mako Shark (*Isurus oxyrinchus*). *Conservation Physiology, 3* https://doi.org/10.1093/conphys/cov044

The shortfin mako shark (*Isurus oxyrinchus*) is a species commonly targeted by commercial and recreational anglers in many parts of the developed world. In Australia, the species is targeted by recreational anglers only, under the assumption that most of the sharks are released and populations remain minimally impacted. If released sharks do not survive, the current management strategy will need to be revised. Shortfin mako sharks are commonly subjected to lengthy angling events; however, their endothermic physiology may provide an advantage over ectothermic fishes when recovering from exercise. This study assessed the post-release survival of recreationally caught shortfin mako sharks using Survivorship Pop-up Archival Transmitting (sPAT) tags and examined physiological indicators of capture stress from blood samples as well as any injuries that may be caused by hook selection. Survival estimates were based on 30 shortfin mako sharks captured off the southeastern coast of Australia. Three mortalities were observed over the duration of the study, yielding an overall survival rate of 90%. All mortalities occurred in sharks angled for < 30 min. Sharks experienced increasing plasma lactate with longer fight times and higher sea surface temperatures (SSTs), increased plasma glucose at higher SSTs and depressed expression of heat shock protein 70 and beta-hydroxybutyrate at higher SSTs. Long fight times did not impact survival. Circle hooks significantly reduced foul hooking when compared with J hooks. Under the conditions of this study, we found that physical injury associated with hook choice is likely to have contributed to an increased likelihood of mortality, whereas the high aerobic scope associated with the species' endothermy probably enabled it to cope with long fight times and the associated physiological responses to capture.

Fujinami, Y., Shiozaki, K., Hiraoka, Y., Semba, Y., Ohshimo, S., & Kai, M. (2021). Seasonal Migrations of Pregnant Blue Sharks *Prionace glauca* in the Northwestern Pacific. *Marine Ecology Progress Series, 658*, 163-179 https://doi.org/10.3354/meps13557

Information on the movements of highly migratory species is important to understand their ecology, including habitat use, population connectivity, and stock structure, to implement appropriate management and conservation measures. The blue shark *Prionace glauca* (Carcharhinidae) is highly migratory, has a global distribution, and is ecologically and economically important as one of the most abundant apex marine predators; however, the migration patterns of pregnant females are unknown. Here, we used pop-up satellite archival tags to elucidate seasonal migration of pregnant blue sharks in the northwestern Pacific. Of 24 tagged adult females, archival data were subsequently obtained for 21 individuals (141.1-243.3 cm precaudal length). Based on ultrasonography or analysis of sex steroid hormones, 17 of these females were confirmed to be pregnant at the time of release. Females with small embryos moved in a northeasterly direction, from subtropical (10-30 degrees N) into temperate (30-40 degrees N) waters during autumn and the following spring; 2 of these females returned to subtropical waters in spring and summer. In contrast, females with large embryos moved in a southwesterly direction, from temperate into subtropical waters during spring and autumn. Tagged sharks also showed regional differences in diving behaviors, reflecting thermal habitats in the ocean environment. Our findings indicate that pregnant blue sharks undergo a seasonal northeast-southwest migration within a year to give birth to pups in productive temperate waters. This is the first report on seasonal reproductive migration of pregnant blue sharks in the global ocean.

Furlong-Estrada, E., Galvan-Magana, F., & Tovar-Avila, J. (2017). Use of the Productivity and Susceptibility Analysis and a Rapid Management-Risk Assessment to Evaluate the Vulnerability of Sharks Caught Off the West Coast of Baja California Sur, Mexico. *Fisheries Research, 194*, 197-208 https://doi.org/10.1016/j.fishres.2017.06.008

Quantitative assessments of shark populations are difficult to undertake due to the scarcity of studies focusing on species identification and landings. We used the productivity and susceptibility analysis and a rapid management-risk assessment (M-risk) method to examine the impact of the artisanal fishery on 29 shark species captured and landed off the west coast of Baja California Sur. We also examined the regulatory measures currently applied to shark fisheries in Mexico to assess their efficacy in mitigating the impact on fishing mortality. Twenty-eight species had low productivity; only Mustelus californicus was placed in the moderate productivity category. Seventeen species had high susceptibility while 12 were placed in the moderate category. Twenty species were placed in the high vulnerability category, and nine in the moderate category. The five most vulnerable species were *Sphyrna zygaena*, Squatina californica, Heterodontus francisci, *Isurus oxyrinchus*, and *Carcharhinus falciformis*. The management-risk is high for all species; artisanal fisheries have a significant impact particularly on coastal shark species, which can be very sensitive to overfishing as well as large species that use the coastal area during the early stages of their development. Research priorities should include studies assessing the elasticity and demographic aspects of S. zygaena and *I. oxyrinchus*. Squatina californica and T. semifasciata require urgent attention due to the risk of extirpation. New regulations and improvements to existing legislation in Mexico may have a positive impact in shark populations, which can be examined in future assessments.

Gelsleichter, J., Sparkman, G., Howey, L. A., Brooks, E. J., & Shipley, O. N. (2020). Elevated Accumulation of the Toxic Metal Mercury in the Critically Endangered Oceanic Whitetip Shark *Carcharhinus longimanus* from the Northwestern Atlantic Ocean. *Endangered Species Research, 43*, 267-279 https://doi.org/10.3354/esr01068

The oceanic whitetip shark *Carcharhinus longimanus* is a widely distributed large pelagic shark species once considered abundant in tropical and warm temperate waters, but recently listed as Critically Endangered by the IUCN due to drastic population declines associated with overfishing. In addition to risks posed to its populations due to overexploitation, oceanic whitetip sharks are also capable of accumulating elevated quantities of harmful environmental toxicants, placing them at special risk from anthropogenic pollution. Herein, we provide the first data on accumulation of the toxic, non-essential metal mercury (Hg) in northwest Atlantic (NWA) oceanic whitetip sharks, focusing on aggregations occurring at Cat Island, The Bahamas. Total Hg (THg) concentrations were measured in muscle of 26 oceanic whitetip sharks and compared with animal length and muscle delta N-15 to evaluate potential drivers of Hg accumulation. THg concentrations were also measured in fin and blood subcomponents (red blood cells and plasma) to determine their value as surrogates for assessing Hg burden. Muscle THg concentrations were among the highest ever reported for a shark species and correlated significantly with animal length, but not muscle delta N-15. Fin, red blood cell, and plasma THg concentrations were significantly correlated with muscle THg. Fin THg content was best suited for use as a surrogate for estimating internal Hg burden because of its strong relationship with muscle THg levels, whereas blood THg levels may be better suited for characterizing recent Hg exposure. We conclude that Hg poses health risks to NWA oceanic whitetip sharks and human consumers of this species.

Gibson, K. J., Streich, M. K., Topping, T. S., & Stunz, G. W. (2021). New Insights into the Seasonal Movement Patterns of Shortfin Mako Sharks in the Gulf of Mexico. *Frontiers in Marine Science, 8* https://doi.org/10.3389/fmars.2021.623104

Highly mobile apex predators such as the shortfin mako shark (mako shark; *Isurus oxyrinchus*) serve an important role in the marine ecosystem, and despite their declining populations and vulnerability to overexploitation, this species is frequently harvested in high abundance in both commercial and recreational fisheries. In 2017, the North Atlantic stock was deemed overfished and to be undergoing overfishing and was recently listed in CITES Appendix II. Effective management of this species can benefit from detailed information on their movements and habitat use, which is lacking, especially in the Gulf of Mexico, a potential mating and parturition ground. In this study, we used satellite telemetry to track the movements of mako sharks in the western Gulf of Mexico between 2016 and 2020. In contrast to previous studies that have primarily tagged juvenile mako sharks (>80% juveniles), similar to 80% of sharks tagged in this study (7 of 9) were presumed to be mature based on published size-at-maturity data. Sharks were tracked for durations ranging from 10 to 887 days (mean = 359 days; median = 239 days) with three mature individuals tracked for >2 years. Mako sharks tagged in this study used more of the northwestern Gulf of Mexico than reported in previous movement studies on juveniles, suggesting potential evidence of size segregation. While one mature female remained in the Gulf of Mexico over a >2- year period, predominantly on the continental shelf, two mature males demonstrated seasonal migrations similar to 2,500 km from the tagging location off the Texas coast to the Caribbean Sea and northeastern United States Atlantic coast, respectively. During these migrations, mako sharks traversed at least 12 jurisdictional boundaries, which also exposed individuals to varying levels of fishing pressure and harvest regulations. Movement ecology of this species, especially for mature individuals in the western North Atlantic, has been largely unknown until recently. These data included here supplement existing information on mako shark movement ecology and potential stock structure that could help improve management of the species.

Gillespie, G. E., & Saunders, M. W. (1994). First Verified Record of the Shortfin Mako Shark, Isurus Oxyrhinchus, and Second Records or Range Extensions for Three Additional Species, from British Columbia Waters. *Canadian Field-Naturalist, 108*(3), 347-350 Retrieved from https://www.biodiversitylibrary.org/page/34263961

The first verifiable record of Shortfin Mako Shark, Isurus oxyrhinchus, from British Columbia is described. Also presented are the second Canadian records for the Pitgum Dragonfish, Opostomias mitsuii, and Oxeye Oreo, Allocyttus, folletti, and southward extension of the known range of the Harlequin Rockfish, Sebastes variegatus.

Gonzalez-Pestana, A., Kouri, J. C., & Velez-Zuazo, X. (2014). Shark Fisheries in the Southeast Pacific: A 61-Year Analysis from Peru. *F1000Res, 3*, 164 https://doi.org/10.12688/f1000research.4412.2

Peruvian waters exhibit high conservation value for sharks. This contrasts with a lag in initiatives for their management and a lack of studies about their biology, ecology and fishery. We investigated the dynamics of Peruvian shark fishery and its legal framework identifying information gaps for recommending actions to improve management. Further, we investigated the importance of the Peruvian shark fishery from a regional perspective. From 1950 to 2010, 372,015 tons of sharks were landed in Peru. From 1950 to 1969, we detected a significant increase in landings; but from 2000 to

2011 there was a significant decrease in landings, estimated at 3.5% per year. Six species represented 94% of landings: blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), smooth hammerhead (*Sphyrna zygaena*), common thresher (*Alopias vulpinus*), smooth-hound (Mustelus whitneyi) and angel shark (Squatina californica). Of these, the angel shark exhibits a strong and significant decrease in landings: 18.9% per year from 2000 to 2010. Peru reports the highest accumulated historical landings in the Pacific Ocean; but its contribution to annual landings has decreased since 1968. Still, Peru is among the top 12 countries exporting shark fins to the Hong Kong market. Although the government collects total weight by species, the number of specimens landed as well as population parameters (e.g. sex, size and weight) are not reported. Further, for some genera, species-level identification is deficient and so overestimates the biomass landed by species and underestimates the species diversity. Recently, regional efforts to regulate shark fishery have been implemented to support the conservation of sharks but in Peru work remains to be done.

Gorman, J., Marra, N., Shivji, M. S., & Stanhope, M. J. (2019). The Complete Mitochondrial Genome of an Atlantic Ocean Shortfin Mako Shark, *Isurus oxyrinchus*. *Mitochondrial DNA Part B-Resources, 4*(2), 3642-3643 https://doi.org/10.1080/23802359.2019.1677524

We report the first complete mitochondrial genome of a shortfin mako shark from the Atlantic Ocean. The genome had 16,700 base pairs and contained 13 protein-coding genes, 2 rRNA genes, 22 tRNA genes, and a non-coding D-loop. There were 81 individual differences compared to the published mitochondrial genome of a shortfin mako from the Pacific Ocean, with most variability found in protein coding genes, especially ND5, ND3, and ND1. These highly variable genes may be useful population markers in future studies, and availability of a second mitogenome will assist with future, genome-scale studies of this IUCN Endangered species.

Griffiths, S. P., Kesner-Reyes, K., Garilao, C., Duffy, L. M., & Roman, M. H. (2019). Ecological Assessment of the Sustainable Impacts of Fisheries (Easi-Fish): A Flexible Vulnerability Assessment Approach to Quantify the Cumulative Impacts of Fishing in Data-Limited Settings. *Marine Ecology Progress Series, 625*, 89-113 https://doi.org/10.3354/meps13032

In fisheries, vulnerability assessments - also commonly known as ecological risk assessments (ERAs) - have been an increasingly popular alternative to stock assessments to evaluate the vulnerability of non-target species in resource- and data-limited settings. The widely-used productivity-susceptibility analysis (PSA) requires detailed species-specific biological information and fishery susceptibility for a large number of parameters to produce a relative vulnerability score. The two major disadvantages of PSA are that each species is assessed against an arbitrary reference point, and PSA cannot quantify cumulative impacts of multiple fisheries. This paper introduces an Ecological Assessment of the Sustainable Impacts of Fisheries (EASI-Fish), a flexible approach that quantifies the cumulative impacts of fisheries on data-limited bycatch species, demonstrated in eastern Pacific Ocean (EPO) tuna fisheries. The method first estimates fishing mortality (F) based on the 'volumetric overlap' of each fishery with the distribution of each species. F is then used in length-structured per-recruit models to assess population vulnerability status using conventional biological reference points. Model results were validated by comparison with stock assessments for bigeye and yellowfin tunas in the EPO for 2016. Application of the model to 24 species of epipelagic and mesopelagic teleosts, sharks, rays, sea turtles and cetaceans and identification of the most vulnerable species is demonstrated. With increasing demands on fisheries to demonstrate ecological sustainability, EASI-Fish allows fishery managers to more confidently identify vulnerable

species to which resources can be directed to either implement mitigation measures or collect further data for more formal stock assessment.

Groeneveld, J. C., Cliff, G., Dudley, S. F. J., Foulis, A. J., Santos, J., & Wintner, S. P. (2014). Population Structure and Biology of Shortfin Mako, *Isurus oxyrinchus*, in the South-West Indian Ocean. *Marine and Freshwater Research, 65*(12), 1045-1058 https://doi.org/10.1071/mf13341

The population structure, reproductive biology, age and growth, and diet of shortfin makos caught by pelagic longliners (2005-10) and bather protection nets (1978-2010) in the south-west Indian Ocean were investigated. The mean fork length (FL) of makos measured by observers on longliners targeting tuna, swordfish and sharks was similar, and decreased from east to west, with the smallest individuals occurring near the Agulhas Bank edge, June to November. Nearly all makos caught by longliners were immature, with equal sex ratio. Makos caught by bather protection nets were significantly larger, males were more frequent, and 93% of males and 55% of females were mature. Age was assessed from band counts of sectioned vertebrae, and a von Bertalanffy growth model fitted to sex-pooled length-at-age data predicted a birth size (L-0) of 90cm, maximum FL (L) of 285cm and growth coefficient (k) of 0.113y(-1). Males matured at 190cm FL, aged 7 years, and females at 250cm, aged 15 years. Litter sizes ranged from nine to 14 pups, and the presence of gravid females in bather protection nets suggested that some pupping occurred in shelf waters. Teleosts (mainly Trachurus capensis) occurred in 84% of stomachs collected on longliners, whereas elasmobranchs (63.5%) were most common in samples collected from bather protection nets, followed by teleosts (43.1%) and cephalopods (36.5%). Larger prey size may be a factor that attracts large makos to coastal waters.

Harry, A. V. (2018). Evidence for Systemic Age Underestimation in Shark and Ray Ageing Studies. *Fish and Fisheries, 19*(2), 185-200 https://doi.org/10.1111/faf.12243

Numerous studies have now demonstrated that the most common method of ageing sharks and rays, counting growth zones on calcified structures, can underestimate true age. I reviewed bomb carbon dating (n=15) and fluorochrome chemical marking (n=44) age validation studies to investigate the frequency and magnitude of this phenomenon. Age was likely to have been underestimated in nine of 29 genera and 30% of the 53 populations studied, including 50% of those validated using bomb carbon dating. Length and age were strongly significant predictors of occurrence, with age typically underestimated in larger and older individuals. These characteristics suggest age underestimation is likely a systemic issue associated with the current methods and structures used for ageing. Where detected using bomb carbon dating, growth zones were reliable up to 88% of asymptotic length (L) and 41% of maximum age (A(Max)). The maximum magnitude of age underestimation, (Max), ranged from five to 34years, averaging 18years across species. Current perceptions of shark and ray life histories are informed to a large extent by growth studies that assume calcified ageing structures are valid throughout life. The widespread age underestimation documented here shows this assumption is frequently violated, with potentially important consequences for conservation and management. In addition to leading to an underestimation of longevity, the apparent loss of population age-structure associated with it may unexpectedly bias growth and mortality parameters. Awareness of these biases is essential given shark and ray population assessments often rely exclusively on life history parameters derived from ageing studies.

Holts, D. B., & Bedford, D. W. (1993). Horizontal and Vertical Movements of the Shortfin Mako Shark, *Isurus oxyrinchus*, in the Southern California Bight. *Australian Journal of Marine and Freshwater Research, 44*(6), 901-909 Retrieved from https://swfsc-publications.fisheries.noaa.gov/publications/CR/1993/9348.PDF

Recreational and commercial fishing effort directed at the shortfin mako shark, *Isurus oxyrinchus*, off the coast of southern California increased markedly in the mid 1980s. However, very little is known about the population size, stock structure or movements of these sharks in the northern Pacific. It is important to determine their role in these waters because the southern California bight may be an important pupping and nursery area for shortfin mako sharks. Acoustic telemetry was used to identify short-term horizontal and vertical movements of three shortfin mako sharks in the southern California bight during the summer of 1989. All three sharks were two-year-old juveniles and were tracked for periods of from 18 to 25 h. They spent 90% of their time in the mixed layer, with only infrequent excursions below the thermocline. Vertical and horizontal movements did not indicate any diel activity pattern associated with distance to the shore or nearby islands or with bottom topography.

Holts, D. B., Julian, A., Sosa-Nishizaki, O., & Bartoo, N. W. (1998). Pelagic Shark Fisheries Along the West Coast of the United States and Baja California, Mexico. *Fisheries Research, 39*(2), 115-125 https://doi.org/10.1016/s0165-7836(98)00178-7

Fisheries targeting elasmobranch resources have experienced a dramatic growth during the past two decades. World-wide elasmobranch landings exceed 600 000 metric tons (mt) annually and have clearly made a significant impact on portions of that resource. In the eastern north Pacific catches of common thresher, shortfin mako and blue sharks may exceed 15 000 mt annually. Nearly 90% of all sharks taken within this area are immature. Like most sharks, these pelagics have low rates of increase which make them quite vulnerable to modem day fishing pressure. Clearly the removal of large segments of juveniles from any population has the potential to decrease the adult population to unsustainable levels. The ability of populations to recover from over-exploitation depends not only on initial stock size, natural mortality, and migration rates, but also upon reducing total fishing mortality. Regulations enacted by special interest groups benefiting only one segment of the resource users, combined with the lack of biological information, have slowed progress towards achieving rational management.

Jordaan, G. L., Santos, J., & Groeneveld, J. C. (2018). Effects of Inconsistent Reporting, Regulation Changes and Market Demand on Abundance Indices of Sharks Caught by Pelagic Longliners Off Southern Africa. *Peerj, 6* https://doi.org/10.7717/peerj.5726

The assumption of a proportional relationship between catch-per-unit-effort (CPUE) and the abundance of sharks caught by pelagic longliners is tenuous when based on fisher logbooks that report only retained specimens. Nevertheless, commercial logbooks and landings statistics are often the only data available for stock status assessments. Logbook data collected from local and foreign pelagic longline vessels operating in four areas off southern Africa between 2000 and 2015 were used to construct standardized CPUE indices for blue sharks *Prionace glauca* and shortfin makos *Isurus oxyrinchus*. Generalized linear mixed models were used to explore the effects of year, month, vessel, fleet and presence of an observer on blue shark and shortfin mako variability. Landing statistics and auxiliary information on the history of the fishery, regulation changes, and market factors were superimposed on

the CPUE indices, to test hypotheses that they would influence CPUE trends. Indices in the West and Southwest (Atlantic) areas were elevated for both species, compared to the South and East (Indian Ocean). The scale of year-on-year CPUE increments, up to an order of magnitude for blue sharks, reflected occasional targeting and retention, interspersed with periods where blue sharks were not caught, or discarded and not reported. Increments were smaller for higher value shortfin makos, suggesting that indices were less affected by unreported discarding. CPUE indices and landings of both shark species have increased in recent years, suggesting increased importance as target species. Analysis of logbook data resulted in unreliable indicators of shark abundance, but when trends were interpreted in conjunction with landings data, disaggregated by area and month, and with hindsight of market demand and regulation changes, anomalies could be explained.

Jordaan, G. L., Santos, J., & Groeneveld, J. C. (2020). Shark Discards in Selective and Mixed-Species Pelagic Longline Fisheries. *PLOS ONE, 15*(8) https://doi.org/10.1371/journal.pone.0238595

The conservation status of several pelagic shark species is considered vulnerable with declining populations, yet data on shark fishing mortality remain limited for large ocean regions. Pelagic sharks are increasingly retained by mixed-species fisheries, or are discarded and not reported by selective fisheries for tunas (Thunnusspp.) or swordfish (*Xiphias gladius*). We estimated the fishing mortality of sharks (landings plus discard mortalities) in a South African-flagged pelagic longline fishery with diverse targeting and discard behaviour. A hierarchical cluster analysis was used to stratify the fleet according to the relative proportions of tunas, swordfish, blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*) landed by individual vessels between 2013 and 2015. A spatial analysis of logbook data indicated that subfleets operated in distinct fishing areas, with overlap. Approximately 5% of all commercial longlines set during 2015 were sampled by a fisheries-independent observer, and the species, discard ratios and physical condition at discard of 6 019 captured sharks were recorded. Blue sharks and shortfin makos dominated observed shark catches, which were comprised of nine species and two species groups. Some 47% of observed sharks were retained and 20% were discarded in good physical condition. Only 4% of shortfin makos were discarded, compared to 68% of blue sharks. Blue shark discard mortality rates were twice as high as published at-vessel mortality rates, suggesting that onboard handling, among other factors, contributed to discard mortalities. Extrapolation to total fishing effort indicated a near 10-fold increase in blue shark and shortfin mako fishing mortality compared to an earlier study (1998-2005). Escalating shortfin mako fishing mortality was attributed to increased targeting to supply higher market demand. Discarding of blue sharks by selective fishing for tunas and swordfish had a greater impact on their fishing mortality than retention by shark-directed fleets. Higher levels of observer sampling are required to increase confidence in discard ratio estimates.

Kabasakal, H. (2015). Occurrence of Shortfin Mako Shark, *Isurus oxyrinchus* Rafinesque, 1810, Off Turkey's Coast. *Marine Biodiversity Records, 8* https://doi.org/10.1017/s1755267215001104

Review of the available literature and the results of the present study revealed that 17 specimens of *Isurus oxyrinchus* were caught between 1950 and 2013. Nine (52.9%) of these verified 17 catches were recorded after 2000. Catches of *I. oxyrinchus* off Turkey's coast include specimens ranging from new-borns (65 cm total length) to huge adults (585 cm total length). A new-born female caught off the coast of Foça on 19 May 2015 represents the smallest free-swimming specimen of *I. oxyrinchus* ever recorded in Turkish waters. The occurrence of a new-born shortfin mako shark off Foça's coast provides new evidence to support the possibility of a mating region of lamniform sharks, including *I. oxyrinchus*, in the

northern Aegean Sea. The seasonal occurrence of both young and adult shortfin mako sharks off Turkey's Aegean and Mediterranean coasts should be monitored to clarify whether the shortfin mako shark is a resident or a vagrant species along the aforementioned coastline.

Kabasakal, H., & De Maddalena, A. (2011). A Huge Shortfin Mako Shark *Isurus oxyrinchus* Rafinesque,1810 (Chondrichthyes: Lamnidae) from the Waters of Marmaris, Turkey. [Un enorme squalo mako dalle pinne corte *Isurus oxyrinchus* Rafinesque, 1810 (Chondrichthyes: Lamnidae) catturato a Marmaris, TurchiaOrjaski primerek vrste atlantski mako *Isurus oxyrinchus* Rafinesque, 1810 (Chondrichthyes: Lamnidae), ujet pri kraju Marmaris, Turcija]. *Annales. Anali za istrske in mediteranske studije. (Series historia naturalis), 21*(1), 21-24 Retrieved from https://zdjp.si/wp-content/uploads/2015/12/kabasakal.pdf

A huge female shortfin mako shark, *Isurus oxyrinchus*, was caught in the late 1950s off Marmaris (SE Aegean Sea, Turkey), by a commercial fisherman. Photographic documentation has been used by the authors to estimate the total length of this specimen at 585 cm (range from 577 to 619 cm). This size greatly exceeds the previous maximum size recorded for the species (a 445 cm long female caught in September 1973, off Six Fours les Plages, France). It is be-lieved that the Marmaris specimen is the largest shortfin mako ever recorded worldwide.

Kai, M. (2020). Numerical Approach for Evaluating Impacts of Biological Uncertainties on Estimates of Stock–Recruitment Relationships in Elasmobranchs: Example of the North Pacific Shortfin Mako. *ICES Journal of Marine Science, 77*(1), 200-215 https://doi.org/10.1093/icesjms/fsz210

Impacts of biological uncertainties on estimates of stock–recruitment relationships (SRRs) in elasmobranchs such as lamniform sharks were evaluated using a numerical approach based on an age-structured model considering reproductive ecology in elasmobranchs. The values of steepness were estimated using several combinations of life history parameters for North Pacific shortfin mako to elucidate whether the numerical approach could identify reasonable values for fundamental life history parameters as well as steepness. The results of the numerical approach indicated that the mean values of steepness and their 95% confidence intervals were highly sensitive to combinations of values for growth rate, maturity ogive, longevity, reproductive cycle, and natural mortality rate. Meanwhile, the most plausible combinations of the biological parameters and values of steepness were identified based on the numerical approach with biological knowledge. The mean values and their standard deviation (SD) for steepness with the Beverton-Holt-SRR model were 0.353 (SD¼0.057) and 0.273 (SD¼0.046) for 2- and 3-year reproductive cycles, respectively. The numerical approach therefore has high potential to become an important tool for estimating SRR in elasmobranchs such as lamniform sharks, and the application of this approach to other elasmobranchs could greatly contribute to improvements in stock assessment and management.

Kai, M., Thorson, J. T., Piner, K. R., & Maunder, M. N. (2017). Spatiotemporal Variation in Size-Structured Populations Using Fishery Data: An Application to Shortfin Mako (*Isurus oxyrinchus*) in the Pacific Ocean. *Canadian Journal of Fisheries and Aquatic Sciences, 74*(11), 1765-1780 https://doi.org/10.1139/cjfas-2016-0327

We develop a length-disaggregated, spatiotemporal, delta-generalized linear mixed model (GLMM) and apply the method to fishery-dependent catch rates of shortfin mako sharks (*Isurus oxyrinchus*) in the North Pacific. The spatiotemporal model may provide an improvement over conventional time-series and spatially stratified models by yielding more precise and biologically interpretable estimates of abundance. Including length data may provide additional information to better understand life history and habitat partitioning for marine species. Nominal catch rates were standardized using a GLMM framework with spatiotemporal and length composition data. The best-fitting model showed that most hotspots for "immature" shortfin mako occurred in the coastal waters of Japan, while hotspots for "subadult and adult" occurred in the offshore or coastal waters of Japan. We also found that size-specific catch rates provide an indication that there has been a recent increasing trend in stock abundance since 2008.

Kai, M., & Yokoi, H. (2017). Evaluation of Harvest Strategies for Pelagic Sharks Taking Ecological Characteristics into Consideration: An Example for North Pacific Blue Shark. *Canadian Journal of Fisheries and Aquatic Sciences, 74*(6), 933-947 https://doi.org/10.1139/cjfas-2016-0170

We have developed a population dynamics model that considers the spatial segregation by sex and ontogenetic stages of pelagic sharks. The model was used to evaluate the performance of harvest strategies based on ecological characteristics. We proposed five harvest strategies for longline fisheries based on the ecological characteristics of blue shark (*Prionace glauca*) in the North Pacific. Management objectives for depleted populations are to increase yield to the level that provides maximum sustainable yield through increases in biomass without collapsing the fishery. Deterministic and stochastic analyses were undertaken. We determined that the harvest of male sharks was robust to uncertainty of environmental changes, reducing the likelihood of fishery collapse and stabilizing yield and mean biomass. The harvest of male sharks was also robust to the uncertainties of biological parameters such as natural mortality and steepness. These results suggested that if there was no sperm limitation or impact on the mating behavior of the species, the harvest of males would be the most appropriate harvest strategy for blue shark in the North Pacific.

Kai, M., Thorson, J. T., Piner, K. R., & Maunder, M. N. (2017). Predicting the Spatio-Temporal Distributions of Pelagic Sharks in the Western and Central North Pacific. *Fisheries Oceanography, 26*(5), 569-582 https://doi.org/10.1111/fog.12217

Spatio-temporal modeling estimates a species distribution function that represents variation in population density over space and time. Recent studies show that the approach may precisely identify spatial hotspots in species distribution, but have not addressed whether seasonal hotspots are identifiable using commonly available fishery data. In this study, we analyzed the seasonal spatio-temporal distribution of pelagic sharks in the western and central North Pacific using fishery catch rates and a generalized linear mixed model with spatio-temporal effects. Different spatial distribution patterns were observed between two shark species. The hotspots of shortfin mako (SFM) appeared in the vicinity of the coastal and offshore waters of Japan and the Kuroshio-Oyashio transition zone (TZ), whereas the hotspots of blue shark (BSH) were widely distributed in the areas from the TZ to the waters of the Emperor Seamount Chain. Shortfin mako distribution changes seasonally with clear north-south movement, which follows higher sea surface temperatures (SST). However, preferred spring and summer water temperature was still colder than those in fall and winter, but not as cold as for BSH, which did not show seasonal north-south movement. BSH exhibits seasonal east-west movement

apparently unrelated to temperature. The spatial fishing effort by season generally follows the seasonal movement of temperature possibly making SFM more vulnerable to the fishery than BSH. These findings could be used to reduce the capture risk of bycatch sharks and to better manage the spatial distribution of fishing for targeted sharks.

Kai, M., Shiozaki, K., Ohshimo, S., & Yokawa, K. (2015). Growth and Spatiotemporal Distribution of Juvenile Shortfin Mako (Isurus Oxyrinchus) in the Western and Central North Pacific. *Marine and Freshwater Research, 66*(12), 1176-1190 https://doi.org/10.1071/Mf14316

This paper presents an estimation of growth curves and spatiotemporal distributions of juvenile shortfin mako shark (Isurus oxyrinchus) in the western and central North Pacific Ocean using port sampling data collected from 2005 to 2013. The monthly length compositions show a clear transition of three modes in the size range of smaller than 150-cm precaudal length (PCL), which were believed to represent the growth of age-0 to age-2 classes, and they were then decomposed into age groups by fitting a Gaussian mixture distribution. Simulation data of lengths at monthly ages were generated from the mean and standard deviation of each distribution, and fit with a von Bertalanffy growth function. Parameters of the estimated growth curves for males and females were 274.4 and 239.4cm PCL for the asymptotic length and 0.19 and 0.25 year(-1) for the growth coefficient indicating apparently faster growth than previously reported. Generalised linear models were applied to age-0 to explore the seasonal changes of PCL by area. They were born during late autumn and winter off the coast of north-eastern Japan, an area known to have relatively high productivity compared with other pelagic areas, and gradually expanded their habitat eastward and northward with the seasons as they grew.

Kanaiwa, M., Semba, Y., & Kai, M. (2021). *Updated Stock Abundance Indices for Shortfin Mako (Isurus oxyrinchus) Estimated by Japanese Longline Observer Data in the North Pacific Ocean*. Paper presented at the ISC/21/SHARKWG-1. Webinar Retrieved from http://isc.fra.go.jp/reports/shark/shark_2021_1.html

In this paper, the updated standardized CPUEs between 2011 and 2019 estimated using the observer data set of Japanese longline operated in North Pacific Ocean were provided. The same statistical model with previous analysis was used. The estimated annual CPUE showed a flat trend between 2011 and 2016 and slightly decreased after 2016.

Kesici, N. B., Dalyan, C., Gönülal, O., Akkaya, A., Lyne, P., Tüzün, S., & Yıldırım, B. (2021). A Preliminary Study on Marine Top Predators Inhabiting Gökçeada Island, the North Aegean Sea. *Journal of the Black Sea / Mediterranean Environment, 27*(1) Retrieved from https://blackmeditjournal.org/wp-content/uploads/3-2021_1_34-48-1.pdf

Marine top predators, such as sharks, teleosts and cetaceans, are great indicators of a healthy ecosystem. The primary goal of this paper is to fill the knowledge gaps on top predators in Gökçeada Island located in the North Aegean Sea. Data on marine top predators were collected through Local Ecological Knowledge. Besides, visual and acoustic field surveys were carried out in the summer and autumn of 2019 and winter of 2020. According to the results of the current study, a total of 464 individuals were reported via social media platforms and questionnaires applied to stakeholders as fishermen, divers and harpooners. Delphinus delphis Linnaeus, 1758, Tursiops truncatus (Montagu,

1821) and Physeter macrocephalus Linnaeus, 1758 were detected during approximately 15 hours of acoustic recording. The records of *Carcharodon carcharias* (Linnaeus, 1758), *Isurus oxyrinchus* Rafinesque, 1810, *Xiphias gladius* Linnaeus, 1758, Thunnus thynnus (Linnaeus, 1758), D. delphis, Stenella coeruleoalba (Meyen, 1833), T. truncatus, Grampus griseus (Cuvier, 1812), P. macrocephalus, Ziphius cavirostris (Cuvier, 1823), Monachus monachus (Hermann, 1779) were listed in this study. A total of 358 individuals of X. gladius and T. thynnus were reported between the years 2017-2020, being the most abundant top predators in the area.

Kinney, M. J., Kacev, D., Kohin, S., & Eguchi, T. (2017). An Analytical Approach to Sparse Telemetry Data. *PLOS ONE, 12*(11), e0188660 https://doi.org/10.1371/journal.pone.0188660

Horizontal behavior of highly migratory marine species is difficult to decipher because animals are wide-ranging, spend minimal time at the ocean surface, and utilize remote habitats. Satellite telemetry enables researchers to track individual movements, but population level inferences are rare due to data limitations that result from difficulty of capture and sporadic tag reporting. We introduce a Bayesian modeling framework to address population level questions with satellite telemetry data when data are sparse. We also outline an approach for identifying informative variables for use within the model. We tested our modeling approach using a large telemetry dataset for Shortfin Makos (*Isurus oxyrinchus*), which allowed us to assess the effects of various degrees of data paucity. First, a permuted Random Forest analysis is implemented to determine which variables are most informative. Next, a generalized additive mixed model is used to help define the relationship of each remaining variable with the response variable. Using jags and rjags for the analysis of Bayesian hierarchical models using Markov Chain Monte Carlo simulation, we then developed a movement model to generate parameter estimates for each of the variables of interest. By randomly reducing the tagging dataset by 25, 50, 75, and 90 percent and recalculating the parameter estimates, we demonstrate that the proposed Bayesian approach can be applied in data-limited situations. We also demonstrate how two commonly used linear mixed models with maximum likelihood estimation (MLE) can be similarly applied. Additionally, we simulate data from known parameter values to test each model's ability to recapture those values. Despite performing similarly, we advocate using the Bayesian over the MLE approach due to the ability for later studies to easily utilize results of past study to inform working models, and the ability to use prior knowledge via informed priors in systems where such information is available.

Kohler, N. E., Casey, J. G., & Turner, P. A. (1995). Length-Weight Relationships for 13 Species of Sharks from the Western North Atlantic. *Fishery Bulletin, 93*(2), 412-418 Retrieved from https://spo.nmfs.noaa.gov/content/length-weight-relationships-13-species-sharks-western-north-atlantic

No abstract.

Kohler, N. E., Turner, P. A., Hoey, J. J., Natanson, L. J., & Briggs, R. (2002). Tag and Recapture Data for Three Pelagic Shark Species: Blue Shark (*Prionace glauca*), Shortfin Mako (*Isurus oxyrinchus*), and Porbeagle (*Lamna nasus*) in the North Atlantic Ocean. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas, 54*(4), 1231-1260 Retrieved from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.631.289&rep=rep1&type=pdf

Tagging and recapture (T/R) information from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) covering the period from 1962 through 2000 are summarized for the blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), and porbeagle (*Lamna nasus*). The extent of the tagging effort, areas of release and recapture, sources of tags and recaptures, capture methods, and movements of tagged sharks are reported by species. Summary information includes number of males and females tagged and recaptured, overall recapture rate, maximum observed speed, distance traveled, and time at liberty. In order to examine regional trends in size and maturation categories, the North Atlantic Ocean is divided into geographical areas. General migration patterns and stock identity by species are summarized and discussed.

Levesque, J. C. (2008). International Fisheries Agreement: Review of the International Commission for the Conservation of Atlantic Tunas. *Marine Policy, 32*(3), 528-533 https://doi.org/10.1016/j.marpol.2007.10.006

To properly manage world fisheries, especially highly migratory species, there are numerous treaties that have been implemented by specialized international fishery commissions. One of the oldest organizations is the International Commission for the Conservation of Atlantic Tunas (ICCAT). The main focus of this review was to summarize the history, roles and responsibilities of ICCAT, and to evaluate ICCAT's management of sharks in general and specifically for shortfin mako (*Isurus oxyrinchus*) shark. This review found that the Convention was established 40 years ago, but it was not until 2004 that the commission conducted its first population assessment on pelagic sharks.

Levesque, J. C. (2013). Commercial Fishery Catch Characteristics and Population Assessment of the Shortfin Mako Shark (*Isurus oxyrinchus*) in the Western North Atlantic Ocean. *Fisheries and Aquaculture Journal, 2013*, 1 Retrieved from https://www.academia.edu/3575253/Commercial_Fishery_Characteristics_and_Population_Assessment_of_the_Shortfin_Mako_Shark_Isurus_oxyrinchus_in_the_Western_North_Atlantic_Ocean

Shortfin mako shark (*Isurus oxyrinchus*) is one of the only pelagic sharks that have any economic value. Given the current conservation status and the general paucity of data on the status of the shortfin mako shark population, the objectives of this study were to characterize the commercial pelagic longline shortfin mako catch and assess its population in the western North Atlantic Ocean using a simple production model. Commercial data indicated that pelagic longline fishing effort has decreased with time, but most of the fishing effort continued to be in the Gulf of Mexico. Catches of shortfin mako shark have decreased over time, but observer data showed that larger animals were taken in the fishery. Overall, the Schaefer model was generally the least sensitive to varying K values, more sensitive to F values, and the most sensitive to r values.

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), e0143008 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 (λ') and the vital parameters, maximum age (Tmax), age at maturity (Tm), annual fecundity (f/Rc)), size at birth (Lb), size at maturity (Lm), and asymptotic length (L1). Group (1) included species with slow growth rates (0.034 yr-1 < k < 0.103 yr-1) and extended longevity (26 yr < Tmax < 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 < Tmax < 26 yr), e.g., starspotted smoothhound Mustelus manazo, gray smoothhound M. californicus, etc.; Group (3) included late maturing species (Lm/L1≧ 0.75) with moderate longevity (Tmax < 29 yr), e.g., pelagic thresher *Alopias pelagicus*, sevengill shark Notorynchus cepedianus. The empirical equation for all data pooled was also developed. The λ' 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.

Liu, S. Y. V., Tsai, W. P., Lee, M., & Chien, H. W. (2020). Accessing Multiple Paternity in the Shortfin Mako Shark (*Isurus oxyrinchus*). *Zool Stud, 59*, e49 https://doi.org/10.6620/zs.2020.59-49

Multiple paternity has been demonstrated in a variety of sharks with different reproductive modes (i.e., viviparous, ovoviviparous, adelphophagy, oviparous), although the number of sires per litter varies considerably among species. To date, such analyses have focused mainly on coastal and nearshore shark species due to the difficulty in sampling oceanic sharks. In the present study, we observed multiple paternity in the oceanic shark *Isurus oxyrinchus* from seven polymorphic microsatellite loci and three litters collected from Nanfangao Fishing Port. Paternity tests showed that an average of 4.6 sires were assigned to each litter of *I. oxyrinchus* using COLONY software, and that the average number of sires dropped to 2.5 when using GERUD. These findings suggest that multiple paternity could be a common reproductive strategy used by the shortfin mako shark, and that this mating system should be integrated into a demographic model to make more accurate population projections and risk analyses in the future.

Lopez, S. A., Abarca, N. L., & Melendez, R. (2013). Heavy Metal Concentrations of Two Highly Migratory Sharks (*Prionace glauca* and *Isurus oxyrinchus*) in the Southeastern Pacific Waters: Comments on Public Health and Conservation. *Tropical Conservation Science, 6*(1), 126-137 https://doi.org/10.1177/194008291300600103

Despite the importance of sharks in structuring the marine food web, their biomass is declining dramatically throughout the world's oceans due to fishing pressures. Sharks caught as by-catch in long-line fisheries are sold for shark fins in the Asian fish market and secondarily as trunk sales for local consumption and fish meal. In order to determine the levels of heavy metals (mercury and lead) in oceanic shark populations in South Pacific waters, analyses of 39 *Prionace glauca* and 69 *Isurus oxyrinchus* were conducted. Mercury (Hg) and lead (Pb) were measured by cold vapor and via acetylene flame techniques, respectively. Mercury concentrations were similar in the studied sharks (p=0.1516), with 0.048 +/- 0.03 mu g.g(-1) w/w for *P. glauca* and 0.034 +/- 0.023 mu g.g(-1) w/w for *I. oxyrinchus*. *P. glauca* showed greater values of lead than *I. oxyrinchus* (p<0.001). Large specimens of both species showed high heavy metal concentration, while sexes showed no statistical differences (p>0.05). The

metal concentrations reported in this work constitute a risk for human health, mainly from the high contributions of lead in tissues of *P. glauca* and *I. oxyrinchus*.

Mancusi, C., Baino, R., Fortuna, C., De Sola, L. G., Morey, G., Bradai, M. N., . . . Serena, F. (2020). Medlem Database, a Data Collection on Large Elasmobranchs in the Mediterranean and Black Seas. *Mediterranean Marine Science, 21*(2), 276-288 https://doi.org/10.12681/mms.21148

The Mediterranean Large Elasmobranchs Monitoring (MEDLEM) database contains more than 3,000 records (with more than 4,000 individuals) of large elasmobranch species from 21 different countries around the Mediterranean and Black seas, observed from 1666 to 2017. The principal species included in the archive are the devil ray (1,868 individuals), the basking shark (935 individuals), the blue shark (622 individuals), and the great white shark (342 individuals). In the last decades, other species such as the thresher shark (187 individuals), the shortfin mako (180 individuals), and the spiny butterfly ray (138) were reported with increasing frequency. This was possibly due to increased public awareness on the conservation status of sharks, and the consequent development of new monitoring programs. MEDLEM does not have homo-geneous reporting coverage throughout the Mediterranean and Black seas and it should be considered as a database of observed species presence. Scientific monitoring efforts in the south-eastern Mediterranean and Black seas arc generally lower than in the northern sectors and the absence of some species in our database does not imply their actual absence in these regions. However, the available data allowed us to analyse the frequency and spatial distribution of records, the size frequencies for a few selected the available data allowed us to analyse the frequency and spatial distribution of records, the size frequencies for a few selected species, the overall area coverage, and which species are involved as bycatch by different fishing gears.

Maxwell, S. M., Scales, K. L., Bograd, S. J., Briscoe, D. K., Dewar, H., Hazen, E. L., . . . Crowder, L. B. (2019). Seasonal Spatial Segregation in Blue Sharks (*Prionace glauca*) by Sex and Size Class in the Northeast Pacific Ocean. *Diversity and Distributions, 25*(8), 1304-1317 https://doi.org/10.1111/ddi.12941

Aim Animal tracking can provide unique insights into the ecology and conservation of marine species, such as the partitioning of habitat, including differences between life history stages or sexes, and can inform fisheries stock assessments, bycatch reduction and spatial management such as dynamic management. Location Northeast Pacific Ocean. Methods We used satellite tracking data from 47 blue sharks (*Prionace glauca*) from the Northeast Pacific to determine movements and home range along the west coast of North America, and sex-size class (immature females, mature males) specific habitat preferences using boosted regression trees. Using a suite of static and dynamic environmental variables, we determined distribution and habitat preferences across summer and fall for each sex-size class. Results We found that there was spatial segregation between sex-size classes particularly in the summer months with immature females found largely north of 33 degrees N, and males south of 35 degrees N. In fall, females travelled south, resulting in an overlap in distributions south of 37 degrees N. Sea surface temperature (SST), latitude and longitude were top predictors. However, immature females and adult males demonstrated unique habitat preferences including SST, with immature females preferring cooler temperatures (SST < 15 degrees C) than adult males in summer, and a broader band of SST than adult males in fall. All models performed well, explaining 50%-67% of deviance, and 23%-41% of deviance when predictions were cross-validated. Main conclusions We provide first insights into coastal movements and habitat preferences of blue sharks in the Northeast Pacific. We found that immature

females undergo a seasonal southward migration in this more coastal habitat, similar to patterns observed in the North Atlantic. We also found some overlap between adult males and immature females in fall months, suggesting the importance of more coastal habitat in managing this species, particularly in determining population structure for blue shark stock assessments, and reducing blue shark bycatch.

McKinney, M. A., Dean, K., Hussey, N. E., Cliff, G., Wintner, S. P., Dudley, S. F. J., . . . Fisk, A. T. (2016). Global Versus Local Causes and Health Implications of High Mercury Concentrations in Sharks from the East Coast of South Africa. *Science of the Total Environment, 541*, 176-183 https://doi.org/10.1016/j.scitotenv.2015.09.074

Conservation concern regarding the overharvest of global shark populations for meat and fin consumption largely surrounds documented deleterious ecosystem effects, but may be further supported by improved knowledge of possibly high levels in their edible tissues (particularly meat) of the neurotoxin, methylmercury (CH3Hg). For many regions, however, little data exist on shark tissue Hg concentrations, and reasons for Hg variation within and among species or across regions are poorly understood. We quantified total Hg (THg) in 17 shark species (total n = 283) from the east coast of South Africa, a top Hg emitter globally. Concentrations varied from means of around 0.1 mg kg(-1) dryweight (dw) THg in hardnose smooth hound (Mustelus mosis) and whale (Rhincodon typus) sharks to means of over 10 mg kg(-1) dw in shortfin mako (*Isurus oxyrinchus*), scalloped hammerhead (*Sphyrna lewini*), white (*Carcharodon carcharias*) and ragged-tooth (Carcharias taurus) sharks. These sharks had higher THg levels than conspecifics sampled from coastal waters of the North Atlantic and North, mid-, and South Pacific, and although sampling year and shark size may play a confounding role, this result suggests the potential importance of elevated local emissions. Values of THg showed strong, species-specific correlations with length, and nearly half the remaining variation was explained by trophic position (using nitrogen stable isotopes, delta N-15), whereas measures of foraging habitat (using carbon stable isotopes, delta C-13) were not significant. Mercury concentrations were above the regulatory guidelines for fish health effects and safe human consumption for 88% and 70% of species, respectively, suggesting on-going cause for concern for shark health, and human consumers of shark meat.

Moreno, J. A., & Moron, J. (1992). Comparative Study of the Genus Isurus (Rafinesque, 1810), and Description of a Form (Marrajo Criollo) Apparently Endemic to the Azores. *Australian Journal of Marine and Freshwater Research, 43*(1), 109-122 https://doi.org/10.1071/MF9920109

Numerous captures of mako sharks (Isurus sp.) are made annually by the Spanish longline fishing fleet in the north-eastern Atlantic Ocean and the western Mediterranean Sea. Sampling of catches allowed us to compare the morphology of two species of Isurus (*I. oxyrinchus* and *I. paucus*) and to document the variations due to size or sex observed in populations exploited by the different fisheries. The distinctive features of a form apparently endemic to the Azores ('marrajo criollo') are defined, and the form's taxonomic identity is discussed. This form is possibly a distinct population of shortfin mako (*I. oxyrinchus*). The presence of longfin mako (*I. paucus*) is confirmed in waters off north-western Morocco, and this species is recorded for the first time off the Iberian peninsula.

Mucientes, G. R., Queiroz, N., Sousa, L. L., Tarroso, P., & Sims, D. W. (2009). Sexual Segregation of Pelagic Sharks and the Potential Threat from Fisheries. *Biology Letters, 5*(2), 156-159 https://doi.org/10.1098/rsbl.2008.0761

Large pelagic sharks are declining in abundance in many oceans owing to fisheries exploitation. What is not known however is whether within-species geographical segregation of the sexes exacerbates this as a consequence of differential exploitation by spatially focused fisheries. Here we show striking sexual segregation in the fastest swimming shark, the shortfin mako *Isurus oxyrinchus*, across the South Pacific Ocean. The novel finding of a sexual 'line in the sea' spans a historical longline-fishing intensity gradient, suggesting that differential exploitation of the sexes is possible, a phenomenon which may underlie changes in the shark populations observed elsewhere.

Musyl, M. K., Brill, R. W., Curran, D. S., Fragoso, N. M., McNaughton, L. M., Nielsen, A., . . . Moyes, C. D. (2011). Postrelease Survival, Vertical and Horizontal Movements, and Thermal Habitats of Five Species of Pelagic Sharks in the Central Pacific Ocean. *Fishery Bulletin, 109*(4), 341-368 Retrieved from https://spo.nmfs.noaa.gov/content/postrelease-survival-vertical-and-horizontal-movements-and-thermal-habitats-five-species

From 2001 to 2006, 71 pop-up satellite archival tags (PSATs) were deployed on five species of pelagic shark (blue shark [*Prionace glauca*]; shortfin mako [*Isurus oxyrinchus*]; silky shark [*Carcharhinus falciformis*]; oceanic whitetip shark [*C. longimanus*]; and bigeye thresher [*Alopias superciliosus*]) in the central Pacific Ocean to determine speciesspecific movement patterns and survival rates after release from longline fishing gear. Only a single postrelease mortality could be unequivocally documented: a male blue shark which succumbed seven days after release. Meta-analysis of published reports and the current study (n=78 reporting PSATs) indicated that the summary effect of postrelease mortality for blue sharks was 15% (95% CI, 8.5-25.1%) and suggested that catch-and-release in longline fisheries can be a viable management tool to protect parental biomass in shark populations. Pelagic sharks displayed species-specific depth and temperature ranges, although with significant individual temporal and spatial variability in vertical movement patterns, which were also punctuated by stochastic events (e.g., El Nino-Southern Oscillation). Pelagic species can be separated into three broad groups based on daytime temperature preferences by using the unweighted pair-group method with arithmetic averaging clustering on a Kolmogorov-Smirnov Dmax distance matrix: 1) epipelagic species (silky and oceanic whitetip sharks), which spent >95% of their time at temperatures within 2 degrees C of sea surface temperature; 2) mesopelagic-I species (blue sharks and shortfin makos, which spent 95% of their time at temperatures from 9.7 degrees to 26.9 degrees C and from 9.4 degrees to 25.0 degrees C, respectively; and 3) mesopelagic-II species (bigeye threshers), which spent 95% of their time at temperatures from 6.7 degrees to 21.2 degrees C. Distinct thermal niche partitioning based on body size and latitude was also evident within epipelagic species.

Nakano, H., & Clarke, S. (2006). Filtering Method for Obtaining Stock Indices by Shark Species from Species-Combined Logbook Data in Tuna Longline Fisheries. *Fisheries Science, 72*(2), 322-332 https://doi.org/DOI 10.1111/j.1444-2906.2006.01153.x

A method of filtering logbook data to obtain estimates of catch per unit effort (CPUE) for sharks has been proposed which simultaneously addresses the issues of under-reporting and the lack of species-specific catch records in historical data. Logbook catch data from vessels with high shark reporting rates

are used to represent catch rates for the abundant blue shark *Prionace glauca* and low reporting vessels' data are used for the main commercially valuable species, the shortfin mako *Isurus oxyrinchus*. Logbook reporting rate filter (RRF) levels are evaluated through analytical and model-based comparisons to species-specific logbook records available since 1994 and shipboard observer data. At the high reporting rates, the >= 80% filter avoids large numbers of false zeros and provides the best fit to observer data for blue shark. At the low reporting rates, the <= 40% filter best matches the observer data for makos, but this filter level includes large numbers of false zeros and sharks of other species. The <= 20% filter produces a dataset that is better targeted to mako catches but considerably under-estimates CPU E relative to observer records. For these reasons, other means of estimating mako catch rates are suggested for further research.

Nakano, H., Matsunaga, H., Okamoto, H., & Okazaki, M. (2003). Acoustic Tracking of Bigeye Thresher Shark *Alopias superciliosus* in the Eastern Pacific Ocean. *Marine Ecology Progress Series, 265*, 255-261 https://doi.org/10.3354/meps265255

Acoustic telemetry was used to identify the short-term horizontal and vertical movement patterns of the bigeye thresher shark *Alopias superciliosus* in the eastern tropical Pacific Ocean during the summer of 1996. Two immature female sharks, 175 and 124 cm PCL (precaudal length), were tracked for 96 and 70 h, respectively, demonstrating very distinct crepuscular vertical migrations similar to those reported for the megamouth shark. The bigeye threshers stayed at 200 to 500 m depth during the day and at 80 to 130 m at night. The deepest dive extends the known depth distribution of the species to 723 m. No ‘fly-glide’ behavior (rapid ascents followed by slower acute-angled descents) was observed for the 2 sharks. However, the opposite behavioral pattern of slow ascents and relatively rapid descents during the night was observed. Since bigeye threshers have large eyes extending upwards onto the dorsal surface of the cranium, it may be more efficient for them to hunt prey which are highlighted against the sea surface from below. Estimated mean swimming speed over the ground ranged from 1.32 to 2.02 km h–1, similar to swordfish and megamouth sharks, and slower than that reported for tunas, billfishes, and other pelagic sharks.

Palacios-Barreto, P., Ramirez-Hernandez, A., Mendoza-Vargas, O. U., & Navia, A. F. (2014). First Record of Mako Shark *Isurus oxyrinchus* (Lamniformes: Lamnidae) Off the Coast of La Media Guajira, Colombian Caribbean. *Latin American Journal of Aquatic Research, 42*(5), 1205-1209 https://doi.org/10.3856/vol42-issue5-fulltext-25

The occurrence of the shortfin mako *Isurus oxyrinchus*, caught by artisanal fishermen using a longline shark fishing, was recorded off the coast of Media Guajira. This is the first record of *I. oxyrinchus* in this area, which extends its geographic distribution into the Colombian Caribbean Sea.

Peter Klimley, A., Beavers, S. C., Curtis, T. H., & Jorgensen, S. J. (2002). Movements and Swimming Behavior of Three Species of Sharks in La Jolla Canyon, California. *Environmental Biology of Fishes, 63*(2), 117-135 https://doi.org/10.1023/a:1014200301213

We tracked six individuals of three shark species, the shortfin mako, *Isurus oxyrinchus*, great white, *Carcharodon carcharias*, and blue, *Prionace glauca*, near the submarine canyon off La Jolla, southern California during the summers of 1995 and 1997. The duration of tracking ranged from 2 to 38 h per

shark. The mode of travel differed in one respect among species. The rate of movement of the endothermic species, the mako and white shark, exceeded that of the ectothermic species, the blue shark. Similarities among species were more common. Firstly, individuals of all three species swam in a directional manner. Secondly, individuals constantly moved up and down in the water column, exhibiting oscillatory or yo-yo swimming. Thirdly, members of the three species swam at the surface for prolonged periods. Finally, the movements of the mako and white sharks were at times loosely associated with bottom topography. We discuss the various adaptive advantages that have been proposed for these behavioral patterns. Oscillatory swimming has been attributed to the following: (1) heating the body in the warm surface waters after swimming in cold, deep water, (2) alternating between two strata of water, one carrying chemical information as to its source, and deriving a direction to that stratum's origin, (3) conserving energy by quickly propelling oneself upward with many tail beats and slowly gliding downward with few beats, and (4) descending to where magnetic gradients are steeper, more perceptible, and useful to guide migratory movements. At the surface, an individual would be able to swim in a straight line by using following features as a reference: (1) celestial bodies, (2) polarized light, or (3) the earth's main dipole field. Furthermore, an individual would conserve energy because of the greater ease to maintaining a warm body in the heated surface waters.

Poisson, F. (2007). *Compilation of Information on Blue Shark (Prionace glauca), Silky Shark (Carcharhinus falciformis), Oceanic Whitetip Shark (Carcharhinus longimanus), Scalloped Hammerhead (Sphyrna lewini) and Shortfin Mako (Isurus oxyrinchus) in the Indian Ocean*. Paper presented at the 3rd Session of the IOTC Working Party on Ecosystems and Bycatch,, Victoria, Seychelles. Working Paper Retrieved from https://www.iotc.org/documents/compilation-information-blue-shark-prionace-glauca-silky-shark-carcharhinus-falciformis

At the Ninth Session of the Indian Ocean Tuna Commission in 2005, the commission adopted the resolution 05/05 , arising from the work of the Compliance Committee, concerning the conservation of sharks caught in association with fisheries managed by IOTC. It is stipulated that Contracting Parties and Cooperating non-Contracting Parties (CPCs) shall annually report their data for shark catches, require that their fishermen use their entire catches of shark (fin-body ratio less than 5%), encourage the release of sharks incidentally caught, promote research on sharks; the Commission requires the working party on By-catch (WPBy) to provide preliminary advice on the stock status of key shark species and provide a research plan and timeline for a comprehensive assessment of these stocks. The purpose of this document is to present some basic biological data needed for assessment of characteristics of the following pelagic sharks species under the management mandate of IOTC. Blue shark (*Prionace glauca*), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark (*Carcharhinus longimanus*), Scalloped hammerhead shark (*Sphyrna lewini*) and Shortfin mako sharks (*Isurus oxyrinchus*) are , in the Indian Ocean, the species most commonly taken by semiindustrial and artisanal fisheries in many countries and also taken as bycatch, by the pelagic longline fisheries and in a less extent by the purse-seine fishery. This document is based primarily on information from literature and studies carried out in Indian Ocean, but when the literature available is scarce we will mention studies available from other oceans. The information pertaining to each species is arranged by paragraphs. Nevertheless, accurate information is sometimes difficult to find. General descriptive characters, illustrations of diagnostic features for each species are given in appendix.

Portell, R. W., Hubbell, G., Donovan, S. K., Green, J. L., Harper, D. A. T., & Pickerill, R. (2008). Miocene Sharks in the Kendeace and Grand Bay Formations of Carriacou, the Grenadines, Lesser Antilles. *Caribbean Journal of Science, 44*(3), 279-286 https://doi.org/10.18475/cjos.v44i3.a2

The Miocene chondrichthyan fauna from the Kendeace and Grand Bay formations consists of five species which have been identified from the remains of teeth. These are *Carcharias taurus* (sand-tiger shark), *Isurus oxyrinchus* (shortfin mako shark), Carcharocles megalodon (mega-tooth shark), Carcharhinus obscurus (requiem shark) and Hemipristis serra (extinct snaggletooth shark). No further skeletal fish remains, Chondrichthyes or Actinopterygii, were discovered. Teeth of Carcharhinus obscurus predominated, by greater than three to one, the other shark species found in these deposits.

Rafrafi-Nouira, S., Diatta, Y., Diaby, A., & Capapé, C. (2019). Additional Records of Rare Sharks from Northern Tunisia (Central Mediterranean Sea). [Nuovi ritrovamenti di squali rari nelle acque della tunisia settentrionale (mediterraneo centrale) dodatni zapisi o pojavljanju redkih morskih psov iz severne tunizije (osrednje sredozemsko morje)]. *Annales : Series Historia Naturalis, 29*(1), 25-34 https://doi.org/10.19233/ASHN.2019.03

Routine investigative monitoring conducted along the northern Tunisian coast allowed us to collect some specimens of large predatory sharks, such as the great white shark, Carcharodon carcharías (Linnaeus, 1758), the shortfin mako *Isurus oxyrinchus* Rafinesque, 1810, and the common thresher shark *Alopias vulpinus* (Bonnaterre, 1788). These captures indicate that these sharks occur in the Mediterranean Sea, however, further records are needed before declaring that viable populations may still be established in the region. On the other hand, the captured specimen of smoothback angelshark Squatina oculata Bonaparte, 1840 could probably be considered as one of the last ones recorded to date in the Mediterranean Sea. The status of the species remains undetermined between extinct and critically endangered.

Ribot-Carballal, M. C., Galvan-Magana, F., & Quinonez-Velazquez, C. (2005). Age and Growth of the Shortfin Mako Shark, *Isurus oxyrinchus*, from the Western Coast of Baja California Sur, Mexico. *Fisheries Research, 76*(1), 14-21 https://doi.org/10.1016/j.fishres.2005.05.004

Age and growth of the shortfin mako shark, *Isurus oxyrinchus*, were estimated using the number of growth marks on whole vertebrae from 109 individuals caught during 2000-2003 off the western coast of Baja California Sur, Mexico. A further 110 individuals were measured to obtain data on the age distribution of the population being fished. Sharks ranged from 77 to 290 cm in total length (TL). A significant linear relationship (r(2) = 0.91) was found between the vertebrae radius and total length, suggesting isometric growth of vertebrae with total length. Distinct bands of heavier calcification were visualized with silver nitrate staining. The periodicity of these growth marks was determined by the frequency of clear and dark margins of the vertebrae in each month of the year. We found that one growth mark is deposited annually. Estimated ages ranged from 0 to 18 years, with the majority of fish being 1-5 years old. Age and TL were used to describe the shortfin mako growth. Estimates of the von Bertalanffy curve parameters for the combined sexes were: L-infinity = 411 cm TL, k = 0.05 year(-1), t(0) = -4.7 years. Our results suggest that shortfin makos are relatively slow growing sharks, which combined with other life-history traits such as a low fecundity and delayed reproduction, makes this species highly susceptible to overfishing.

Rogers, P. J., Huveneers, C., Goldsworthy, S. D., Cheung, W. W. L., Jones, G. K., Mitchell, J. G., & Seuront, L. (2013). Population Metrics and Movement of Two Sympatric Carcharhinids: A Comparison of the Vulnerability of Pelagic Sharks of the Southern Australian Gulfs and Shelves. *Marine and Freshwater Research, 64*(1), 20-30 https://doi.org/10.1071/mf11234

The dusky shark Carcharhinus obscurus and the bronze whaler *Carcharhinus brachyurus* are large-bodied, marine predators that inhabit coastal and shelf waters of southern Australia. C. obscurus is considered to be among the most vulnerable pelagic sharks to overexploitation. This study focussed on population metrics and movement patterns of these sympatric species. Litters from two pregnant C. brachyurus were examined; these comprised 20 and 24 embryos, respectively. Tagging data indicated that 75% of whaler sharks tagged in this region by recreational fishers were juveniles, and 58% of recaptures occurred within 50 km of the tagging locations. Fishery catch samples comprised 99% juvenile C. brachyurus and C. obscurus. Our findings suggested that semi-protected gulf waters represented ecologically significant habitats of juveniles. A fuzzy-logic model showed that in terms of relative vulnerability to fishing, C. brachyurus ranked in the mid to lower end of the spectrum, when compared with six sympatric pelagic shark species, including the white shark, *Carcharodon carcharias*. Our findings emphasised a need for improvement to management measures for these carcharhinids, which are likely to play a significant role in the functioning of the temperate gulf and shelf ecosystems.

Rogers, P. J., Huveneers, C., Page, B., Goldsworthy, S. D., Coyne, M., Lowther, A. D., . . . Seuront, L. (2015). Living on the Continental Shelf Edge: Habitat Use of Juvenile Shortfin Makos *Isurus oxyrinchus* in the Great Australian Bight, Southern Australia. *Fisheries Oceanography, 24*(3), 205-218 https://doi.org/10.1111/fog.12103

We used satellite telemetry data to investigate the movement patterns and habitat use of juvenile shortfin makos *Isurus oxyrinchus* (Lamnidae) tagged in the Great Australian Bight, southern Australia. Tracking durations ranged from 49-672days and six deployments were >1year. During winter and spring, some shortfin makos migrated to the tropical NE Indian Ocean and Coral Sea, and the Subtropical Front region. One shortfin mako undertook an extended migration of 25550km across the Indian Ocean. Areas characterized by sea-mounts in the NE Indian Ocean, the oceanic Subtropical Front region, and the continental shelf edge (200-m depth) and slope canyons were visited by several sharks. Juvenile shortfin makos used the outer continental shelf, the shelf edge, the slope and oceanic waters during migrations and mostly exhibited fidelity in the mid-outer shelf, the shelf edge and slope habitats characterized by high bathymetric relief and oceanographic frontal gradients. Our findings highlighted that the continental shelf and slope and associated submarine canyons of the Great Australian Bight represent ecologically important habitats for juvenile shortfin makos. The findings of this study will be pertinent during future management processes for this highly migratory species in this Southern Hemisphere region.

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* 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).

Runcie, R., Holts, D., Wraith, J., Xu, Y., Ramon, D., Rasmussen, R., & Kohin, S. (2016). A Fishery-Independent Survey of Juvenile Shortfin Mako (*Isurus oxyrinchus*) and Blue (*Prionace glauca*) Sharks in the Southern California Bight, 1994-2013. *Fisheries Research, 183*, 233-243 https://doi.org/10.1016/j.fishres.2016.06.010

A fishery-independent abundance survey was initiated by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG) in 1994 to track the relative abundance and size of juvenile shortfin mako (*Isurus oxyrinchus*) and blue (*Prionace glauca*) sharks in the Southern California Bight (SCB). The survey was designed based on data from an experimental commercial shark longline fishery that operated in the SCB during 1988-1991. Survey sets were conducted annually during the summer months within seven 10 x 10 min spatial blocks in the SCB close to the California Channel Islands. Between 1994 and 2013, survey effort totaled 460 sets. The standardized catch-per-unit-effort (CPUE) of shortfin mako showed a generally declining trend from 1994 through 2010 with increases during the final years to a level similar to those of the mid-1990s. For blue sharks, the standardized CPUE showed a generally declining trend throughout the time series with the lowest values in 2012 and 2013, and an anomalously high CPUE in 2000. Catch rates varied across the survey area with fewer, larger sharks caught in the more northern blocks of the survey. Sharks of age classes 0-2 represented the majority of those caught in the survey (approximately 81% of blue sharks and 58% of makos), yet there was variability in the sizes of blue and mako sharks caught by year. The sex ratio of age-0 sharks caught was not different from 1:1 for shortfin makos, but skewed toward females for blue sharks. Although the survey area is relatively small and results show interannual and spatial variability in CPUE that is not fully understood, these data represent the first and only fishery-independent survey that has targeted these shark species in the SCB. The results of the survey and associated data provide useful information regarding regional relative abundance, size- and sex-compositions, and spatial distributions of shortfin mako and blue sharks, all of which are essential for stock assessments and fisheries management.

Salmon, T., Rangel, B. d. S., Malavasi-Bruno, C. E., & Kfoury-Jr, J. R. (2021). New Records and Preliminary Reproductive Aspects of Elasmobranchs of the Trindade-Martin Vaz Insular Complex. *Oecologia Australis, 25*(01), 159-165 https://doi.org/10.4257/oeco.2021.2501.15

Here we presented records of elasmobranchs obtained during a longline pelagic fishing monitoring around the Trindade-Martin Vaz insular complex, including one new record. New information on the

reproductive aspects of the blue shark (*Prionace glauca*) and pelagic stingray (Pteroplatytrygon violacea) suggest the use of this area as mating and parturition ground for these species. The most abundant species was the P. glauca (N = 65), followed by shortfin mako shark *Isurus oxyrinchus* (N = 12). We also recorded for the first time the smooth hammerhead shark *Sphyrna zygaena* (N = 3) and the bigeye thresher shark *Alopias superciliosus* (N = 2), and other shark species previous reported for the insular complex, including the oceanic whitetip *Carcharhinus longimanus* (N = 2), and the tiger shark Galeocerdo cuvier (N = 1). Our findings highlight the importance of further studies at the Trindade-Martin Vaz insular complex considering the pelagic biodiversity and reproductive aspects of elasmobranchs.

Schrey, A. W., & Heist, E. J. (2003). Microsatellite Analysis of Population Structure in the Shortfin Mako (*Isurus oxyrinchus*). *Canadian Journal of Fisheries and Aquatic Sciences, 60*(6), 670-675 https://doi.org/10.1139/f03-064

Microsatellite analysis of the shortfin mako, shark (*Isurus oxyrinchus*) revealed very weak evidence of population structure. Samples collected from the North Atlantic, South Atlantic, North Pacific, South Pacific, and Atlantic, and Pacific coasts of South Africa were screened at four microsatellite loci. Multilocus measures of population subdivision were much lower than expected (F-ST = 0.0014, P = 0.1292; R-ST = 0.0029, P = 0.019). Power analysis revealed that the study had a high level of power (>0.995) to detect the magnitude of FST expected based on a previous study of mtDNA and assumptions of equal male and female dispersal. Thus, integrating the results from microsatellite- and mitochondrial-based studies may provide evidence for gender-biased dispersal for the shortfin mako.

Semba, Y. (2018). Significance of Sex-Specific Ecological and Life History Traits on the Sustainable Exploitation of Sharks. In *Fish Population Dynamics, Monitoring, and Management: Sustainable Fisheries in the Eternal Ocean.* I. Aoki, T. Yamakawa, & A. Takasuka (Eds.), (pp. 77-104) https://doi.org/10.1007/978-4-431-56621-2_5

Sharks, which maintain the role of top predator in aquatic ecosystems, have a reproductive system and life history traits that are quite different from those of most teleosts, including internal fertilization, slow growth, high age at maturity, and the live birth of only a few well-formed offspring. Although shark species show diversity in many traits such as body size, morphology, diet, habitat (vertically, horizontally, and latitudinally), and reproductive system (ovoviviparous and viviparous), sexual difference in various phenotypic traits is one of their major characteristics. Sex-specific phenotypic traits such as life history parameters and sexual segregation are illustrated, focusing on shortfin mako and other species. A survey of the literature on growth suggests that slow growth and large body size in females are a major trend in sharks with significant intersexual difference in growth. Sexual segregation of sharks is reported with varying degrees of resolution, but its pattern is variable depending on the species, and the underlying mechanisms are largely unclear. The implication of intersexual difference in life history and behavioral traits is discussed from both evolutional and practical points of view. Existing studies that have evaluated the effect of sexual difference suggest the importance of including sex-specific traits in stock assessment and management, especially for species with marked sexual difference. Given its significance, both the study of sexual difference in the biological characteristics and the collection of sex-specific information on fishery statistics are important for understanding population dynamics and the sustainable exploitation of shark species.

Semba, Y. (2021). *Length Frequency of Shortfin Mako (Isurus oxyrinchus) Reported in the Japanese Observer Program between 2011 and 20191*. Paper presented at the ISC/21/SHARKWG-1. Webinar Retrieved from http://isc.fra.go.jp/reports/shark/shark_2021_1.html

This document paper summarizes the length frequency data of shortfin mako collected by the Japanese observer program between 2011 and 2019. Majority of size data was collected in the area north of 30°N and west of 175° E, which is part of main ground of shallow-set longline fishery targeting swordfish and blue shark. The annual median and quartile percentiles of catch at size of shortfin mako in PCL indicated that remarkable temporal change of body size was not clearly observed and relatively stable in the main fishing ground of offshore shallow-set longline fishery where juvenile dominates. Although coverage of observer data is not high, combined with the abundance index estimated based on shallow-set logbook data and current result, it is suggested that population decrease is unlikely to occur after the last year (i.e., 2016) of stock assessment conducted in 2018.

Semba, Y., Nakano, H., & Aoki, I. (2009). Age and Growth Analysis of the Shortfin Mako, *Isurus oxyrinchus*, in the Western and Central North Pacific Ocean. *Environmental Biology of Fishes, 84*(4), 377-391 https://doi.org/10.1007/s10641-009-9447-x

We determined the age and growth rates of male and female shortfin makos, (*Isurus oxyrinchus*), from the western and central North Pacific Ocean. Growth band pairs were counted on half-cut vertebral centra using a shadowing method. In this method, we focused on the ridges on the surface of the centra, consisting of a convex and concave structure. After comparing four enhancing methods, we decided on the use of shadowing method for aging. Vertebrae from 128 males and 147 females were examined. The centrum edge analysis suggested annual band pair formation. Von Bertalanffy growth curves were fitted separately to the length-at-age data for males and females with birth length fixed. Until approximately 7 years of age, both sexes showed similar growth rates; thereafter, males showed a significantly slower growth rate compared to females. It was suggested males and females mature at approximately 6 years and 16 years, respectively. These life-history characteristics suggest relatively low productivity for this species, which agrees with reports on populations in other geographic regions.

Sepulveda, C. A., Kohin, S., Chan, C., Vetter, R., & Graham, J. B. (2004). Movement Patterns, Depth Preferences, and Stomach Temperatures of Free-Swimming Juvenile Mako Sharks, *Isurus oxyrinchus*, in the Southern California Bight. *Marine Biology, 145*(1), 191-199 https://doi.org/10.1007/s00227-004-1356-0

Acoustic telemetry was used to track vertical and horizontal movement patterns and to monitor the stomach temperatures of seven juvenile shortfin mako sharks (*Isurus oxyrinchus* Rafinesque) in the Southern California Bight from July to November 2002. Makos (80-145 cm fork length, FL) were attracted to the tracking vessel, where they were fed a mackerel containing an acoustic transmitter that reported temperature and pressure. Tracks ranged from 6.8-45.4 h. Collectively, the mako sharks spent 80% of the track record at 0-12 m, 15% at 12-24 m, and 5% at depths >24 m. The average horizontal swimming speed was 2.3 km h(-1) or 0.55 FLs s(-1), and the greatest distance traveled was 145 km in 45.4 h. For the six tracks >21 h, there was a positive correlation between body size and maximum depth. Makos used more of the water column during daylight hours. Mean stomach temperature was 3.8+/-1.5degreesC above ambient, and body size was positively correlated with both maximum and average

stomach temperature. Stomach content analyses of four makos captured at the end of tracking verified the occurrence of feeding events as indicated by changes in stomach temperature.

Shiffman, D. S., Frazier, B. S., Kucklick, J. R., Abel, D., Brandes, J., & Sancho, G. (2014). Feeding Ecology of the Sandbar Shark in South Carolina Estuaries Revealed through Delta C-13 and Delta N-15 Stable Isotope Analysis. *Marine and Coastal Fisheries, 6*(1), 156-169 https://doi.org/10.1080/19425120.2014.920742

Stable isotope ratios of carbon and nitrogen (delta C-13 and delta N-15) from muscle samples were used to examine the feeding ecology of a heavily exploited shark species, the Sandbar Shark Carcharhinus plumbeus. Two hundred and sixty two Sandbar Sharks were sampled in five South Carolina estuaries. There were no significant differences in average delta C-13 or delta N-15 signatures between estuaries, between sampling years, or between male and female Sandbar Sharks, suggesting that these variables do not affect diet. A potential ontogenetic diet shift between young-of-year and juvenile Sandbar Sharks in South Carolina, similar to a shift previously described in Virginia and Hawaii populations, is suggested by significant differences in average delta C-13 and average delta N-15 signatures between these age-classes. Results confirm that Sandbar Sharks in South Carolina are generalist predators and that juvenile Sandbar Sharks have a wider diet breadth than young-of-year sharks, a pattern common in elasmobranchs. Sandbar Shark diet in South Carolina is similar to that found in previous stomach content analysis studies. This study also demonstrates that nonlethal sampling methods can be applied to sharks to obtain diet and trophic information, including the detection of ontogenetic shifts in diet.

Simpfendorfer, C. A., Hueter, R. E., Bergman, U., & Connett, S. M. H. (2002). Results of a Fishery-Independent Survey for Pelagic Sharks in the Western North Atlantic, 1977–1994. *Fisheries Research, 55*(1), 175-192 https://doi.org/10.1016/S0165-7836(01)00288-0

Catch and effort data from a fishery-independent longline survey in the western North Atlantic were used to investigate the biology, distribution and abundance of pelagic sharks. Data were restricted to the period from 1977 to 1994, and for the months of June–August. Catches were dominated by the blue shark (*Prionace glauca*), with smaller numbers of shortfin mako (*Isurus oxyrinchus*), porbeagle (*Lamna nasus*), thresher (Alopias spp.) and silky (*Carcharhinus falciformis*) sharks. Detailed analysis was restricted to P. glauca due to small sample sizes for the other species. Male blue sharks were caught more often than females. The catches included juveniles and adults of both sexes but very few adult females. Annual sex ratios varied, but normally favored males. Monthly sex ratios were even in June, but favored males in July and August. Due to differences in occurrence between males and females, distribution and abundance data were analyzed separately for each sex. Male catch per unit effort (CPUE) was highest between 15 and 20°C, while female CPUE peaked at approximately 15°C and decreased with increasing water temperatures. CPUE for males and females were standardized using a generalized linear model with years, months and day-night as factors. Males showed an approximately 80% decline between the mid-1980s and the early 1990s, while a significant change in female catch rates could not be demonstrated. The results of the analyses are discussed in relation to fishery-dependent studies in the western North Atlantic, along with previous work on the biology and distribution of pelagic sharks.

Stevens, J. D. (2010). Epipelagic Oceanic Elasmobranchs. In *Sharks and Their Relatives Ii: Biodiversity, Adaptive Physiology, and Conservation.* J. C. Carrier, J. A. Musick, & M. R. Heithaus (Eds.), (pp. 3-35) Retrieved from https://www.routledge.com/Sharks-and-Their-Relatives-II-Biodiversity-Adaptive-Physiology-and-Conservation/Carrier-Musick-Heithaus/p/book/9781420080476

No abstract.

Stevens, J. D., Bradford, R. W., & West, G. J. (2010). Satellite Tagging of Blue Sharks (*Prionace glauca*) and Other Pelagic Sharks Off Eastern Australia: Depth Behaviour, Temperature Experience and Movements. *Marine Biology, 157*(3), 575-591 https://doi.org/10.1007/s00227-009-1343-6

Satellite telemetry was used to study the movements and behaviour of ten blue sharks and one individual each of shortfin mako, thresher and bigeye thresher off eastern Australia. The tracks showed latitudinal movements of up to 1,900 km, but none of the sharks travelled away from the eastern Australian region. Tracking periods did not exceed 177 days. All species showed oscillatory dive behaviour between the surface layers to as deep as 560-1,000 m. Blue sharks spent 35-58% of their time in < 50 m depths and 10-16% of their time in > 300 m. Of these four species, the bigeye thresher spent the least time in the surface layers and the most time at > 300 m depth. All four species showed clear diel behaviour generally occupying shallower depths at night than during the day. Blue sharks were mainly in 17.5-20.0A degrees C water, while the thresher sharks showed a more bimodal temperature distribution.

Torres, P., da Cunha, R. T., & Rodrigues, A. D. (2016). The Elasmobranch Fisheries of the Azores. *Marine Policy, 73*, 108-118 https://doi.org/10.1016/j.marpol.2016.07.027

In the Northeast Atlantic, elasmobranchs are a common bycatch in many fisheries, including demersal trawls, longlines, or gillnets and many countries do not have regulations or any control over the amount taken. In the Mid Atlantic, the Azores EEZ (Exclusive Economic Zone), small-scale fishing operations, artisanal and hook-and-line fishing methods are responsible for part of local total landed elasmobranch biomass, although some species are specifically focused and severely harvested by international large-scale fleets. This work provides a review and analysis of the commercial elasmobranch fisheries in the Azores EEZ, and its evolution over the last two decades, highlighting management priorities, taking into account the Northeast Atlantic elasmobranch fisheries status. In the Mid-Atlantic, elasmobranch fisheries mainly target 4 species, that are usually landed as bycatch: the tope shark (*Galeorhinus galeus*) and the thornback ray (Raja clavata), captured mainly by local demersal artisanal fisheries, the blue shark (*Prionace glauca*) and the shortfin mako shark (*Isurus oxyrinchus*) captured by a more industrialised fleet, including those from foreign nations. Considering elasmobranchs life history traits and fishery history, caution is advised in the development of a management strategy focusing on these species, considering the Northeast Atlantic context and regional, local and national interests.

Tsai, W. P., Chang, Y. J., & Liu, K. M. (2019). Development and Testing of a Bayesian Population Model for the Bigeye Thresher Shark, *Alopias superciliosus*, in an Area Subset of the Western North Pacific. *Fisheries Management and Ecology, 26*(3), 269-294 https://doi.org/10.1111/fme.12347

A Bayesian population modelling tool integrating separable virtual population analysis, per-recruit models and age-structured demographic analysis was developed for the bigeye thresher *Alopias superciliosus* (Lowe) population in an area subset of the western North Pacific. The mortality rates for years 1989-2016 were estimated, various biological reference points and associated risks of decline were also estimated, and alternative harvest strategies for the stock were evaluated. Estimates of the posterior mean of fishing mortality for bigeye thresher shark suggest fishing pressure has been high in recent years (2011-2016). The estimated population growth rate (lambda) (without fishing) obtained from age-structured demographic model was relatively low (lambda = 1.01 per year; 95% confidence intervals of 1.00 and 1.03 per year). Risk analyses revealed that only low levels of fishing pressure (10% of the current fishing pressure) over a wide range of ages could maintain a relatively low risk of population decline for bigeye threshers. Sensitivity testing indicated that the model is robust to prior specification. The developed framework could be used as an assessment tool to evaluate the risk of decline for other widely distributed pelagic shark species where insufficient catch and effort data are available.

Tsai, W. P., Sun, C. L., Punt, A. E., & Liu, K. M. (2014). Demographic Analysis of the Shortfin Mako Shark, *Isurus oxyrinchus*, in the Northwest Pacific Using a Two-Sex Stage-Based Matrix Model. *ICES Journal of Marine Science, 71*(7), 1604-1618 https://doi.org/10.1093/icesjms/fsu056

Most demographic models are single sex, and assume both sexes have the same vital rates. However, many species, including the shortfin mako shark, are sexually dimorphic in vital rates, which suggests the need for two-sex models. In this study, a two-sex stage-structured matrix model was constructed to estimate shortfin mako shark demography and population dynamics. Monte Carlo simulations were used to evaluate the impact of uncertainties on the estimate of population growth rate. The number of shortfin mako sharks is found to be dropping under current conditions, but will stabilize if size-limit management is implemented. The simulations indicated that population growth rate estimates are mainly influenced by the uncertainty related to survival rate and fecundity. The effects of uncertainty regarding the age at maturity and longevity were found to be relatively minor. Future research should focus on obtaining estimates of natural mortality and reproductive traits for this species to improve the accuracy of demographic estimates.

Tsai, W. P., Liu, K. M., Punt, A. E., & Sun, C. L. (2015). Assessing the Potential Biases of Ignoring Sexual Dimorphism and Mating Mechanism in Using a Single-Sex Demographic Model: The Shortfin Mako Shark as a Case Study. *ICES Journal of Marine Science, 72*(3), 793-803 https://doi.org/10.1093/icesjms/fsu210

Most demographic models explicitly track the dynamics of a single sex. However, single-sex models may lead to rather poor results when vital rates and other demographic parameters differ between the sexes. Consequently, the population may not be optimally managed if management measures are based on a single-sex model, which suggests the need for two-sex models. The consequences of ignoring sexual dimorphism and mating mechanisms when proposed management strategies are based on single-sex demographic models are illustrated for shortfin mako shark, *Isurus oxyrinchus*, in the Northwest Pacific Ocean. Analyses based on single-sex models would underestimate the probability of decline risk. The findings imply that management decisions should be based on sex-specific models to better achieve management goals. The mating mechanism principally affects the proportion of breeding females, which has a large impact on the perceived population growth rate. Which mating function best

describes the dynamics of shortfin mako populations is still unknown. More research is needed to avoid making inaccurate management decisions, such as genetic paternity studies to clarify the mating mechanism for this species.

Udovicic, D., Ugarkovic, P., Madiraca, F., & Dragicevic, B. (2018). On the Recent Occurrences of Shortfin Mako Shark, *Isurus oxyrinchus* (Rafinesque, 1810) in the Adriatic Sea. *Acta Adriatica, 59*(2), 237-243 https://doi.org/10.32582/aa.59.2.10

Eleven individuals of the shortfin mako shark, *Isurus oxyrinchus* (Rafinesque, 1810) have been recorded in the period from 2014 to 2018 in the Adriatic Sea. The specimens presented in the paper were identified on the basis of photographic evidence. Occurrences of juvenile and newborn specimens suggests that Adriatic Sea could serve as a nursery area for this species, especially its eastern part. A review of the previously documented occurrences of this species in the Adriatic Sea is given in this article.

Vaudo, J. J., Byrne, M. E., Wetherbee, B. M., Harvey, G. M., & Shivji, M. S. (2017). Long-Term Satellite Tracking Reveals Region-Specific Movements of a Large Pelagic Predator, the Shortfin Mako Shark, in the Western North Atlantic Ocean. *Journal of Applied Ecology, 54*(6), 1765-1775 https://doi.org/10.1111/1365-2664.12852

1. As upper level predators, sharks serve an important role in marine ecosystems, but are often at risk from fisheries. Successful management of these species will require detailed information about their movements and distributions. 2. Using satellite telemetry, we investigated the long-term horizontal movements and seasonal distributions of shortfin mako sharks *Isurus oxyrinchus* in the western North Atlantic Ocean. 3. Twenty-six sharks (14 USA, 12 Mexico) were tracked for durations of 78-527 days. Ten sharks were tracked for > 1 year. Sharks displayed region-specific movements, with little distributional overlap between the Gulf of Mexico and Caribbean Sea, and the western North Atlantic. Sharks tagged off the USA ranged over a larger area, including shelf and pelagic habitats. Their core distribution was largely over the continental shelf and fluctuated seasonally, ranging from South Carolina, USA, in the winter to Nova Scotia, Canada, in the autumn, and appeared to follow seasonal productivity peaks while favouring warmer waters. Sharks tagged off Mexico displayed more restricted movements, largely confined to shelf habitats, with core activity centred year-round on the eastern Campeche Bank, Mexico. 4. Sharks moved across the jurisdictional management boundaries of 17 nations, and the proportion of tracked sharks harvested (22%) was twice that obtained from previous fisheries- dependent, conventional tagging studies. 5. Sharks also displayed considerable variability in movements, with seven sharks tagged off the USA making long-distance, highly directional southern excursions into unproductive subtropical/tropical waters before returning north. 6. Policy implications. The large-scale and region-specific movements of shortfin mako sharks underscore the need for close cooperation amongst western North Atlantic nations and implementation of regionally and seasonally specific management strategies. The movement patterns also provide baseline information, which could be used in spatially explicit stock assessment models. Identification of high-use areas by shortfin mako sharks provides focal areas for quantifying interactions with fisheries. The high harvest rate observed in our fisheries- independent tracking study raises questions about the true rate of fisheries mortality experienced by shortfin mako sharks, calling for a cautionary interpretation of past stock assessments used to determine management policy for this highly migratory species of conservation concern.

Velez-Marin, R., & Marquez-Farias, J. F. (2009). Distribution and Size of the Shortfin Mako (*Isurus oxyrinchus*) in the Mexican Pacific Ocean. *Pan-American Journal of Aquatic Sciences, 4*(4), 490-499 Retrieved from https://panamjas.org/pdf_artigos/PANAMJAS_4(4)_490-499.pdf

The shortfin mako, *Isurus oxyrinchus*, is a highly migratory species with wide distribution. It is caught directly both as target and bycatch in pelagic fisheries. Detailed knowledge of the biology and nursery grounds of shortfin mako in Eastern Pacific Ocean is limited. Hence, insights on this issue will help understand the structure of the popula tion for further assessment. In the present study we analyze the catch and biological data collected by scientific observers aboard longline vessels during fishing periods from 1986 to 2003. The examined sharks ranged from 55 to 264 cm in fork length (FL) (63-276 cm total length, TL) and from 7 to 72 kg in weight. No sex-specific differences were observed between the weight -length relationship. Shortfin makos are caught in Northwest Mexico, especially along the southwest Baja California Peninsula, in the vicinity of the Marias and Revillagigedo Islands. In the same area, young makos of 55 to 88 cm FL (63-100 cm TL) were found from January to August. Presumably, these juveniles inhabit the corridor from the Southern California Bight to an oceanic polygon that includes the Marias and Revillagigedo Islands, suggesting a nursery for this species.

Vetter, R., Kohin, S., Preti, A., McClatchie, S., & Dewar, H. (2008). Predatory Interactions and Niche Overlap between Mako Shark, *Isurus oxyrinchus*, and Jumbo Squid, Dosidicus Gigas, in the California Current. *California Cooperative Oceanic Fisheries Investigations Reports, 49*, 142-156 Retrieved from http://calcofi.org/publications/calcofireports/v49/Vol_49_Vetter_web.pdf

Recent scientific and anecdotal observations have documented a range expansion of jumbo, squid, Dosidicus gigas, into the Southern California Bight (SCB) and northward in the California Current Large Marine Ecosystem. The increase in squid abundance at higher latitudes has generated hypotheses concerning, the ecosystem changes that may have permitted this expansion. Top-down explanations suggest that overharvest of higher trophic level species such as tunas and billfishes creates a trophic cascade that increases survivorship of jumbo squid. Bottom-up explanations suggest that changes in ocean climate, including temperature and hypoxia, may favor an expanded range for jumbo squid. Here we present information on: (1) predatory interactions between the mako shark and jumbo squid in the SCB, (2) vertical niche of mako sharks and potential for a hypoxic refuge for jumbo squid, and (3) changes in the oxygen minimum zone (OMZ) and trends in epi- and mesopelagic prey. Make, sharks examined during the 2006 and 2007 NOAA Fisheries Southwest Fisheries Science Center juvenile Shark Longline Survey had a high incidence of scars inflicted by jumbo squid. Diet studies based on the California Drift Gillnet Fishery, 2002-07 indicate that jumbo squid accounted for a substantial portion of the mako diet. Bioenergetic calculations suggest that the average 1.8 kg mako taken in the fishery would need 56-113 kg of squid to meet its annual dietary requirements. The high-resolution diel activity records of two representative animals indicate makos remained near the surface at night and were able to exploit the water column from the surface to a maximum depth of 300 m during the day. The maximum depth of dives corresponded to oxygen concentrations as low as 1.25 ml/L. Previous studies indicate that jumbo squid inhabit a depth range from the surface to the upper bounds of the OMZ where oxygen concentration is 0.5 ml/L or less. Jumbo squid in the SCB may have a deepwater refuge from mako sharks below 1.25 ml O-2/L, but are clearly available to mako during diet vertical migrations. Examination of the CalCOFI database for changes in oxygen content and larval fish counts over the previous 56 years indicates a shoaling of the OMZ and periodic changes in abundance of epi- and mesopelagic prey species, but did not reveal a simple relationship between oxygen, prey availability, and

range expansion. Better estimates of squid and mako population size and mako removal rates are needed to fully understand the impact of mako sharks on jumbo squid abundance.

William, A. W., Keith, A. B., & Karen, L. S. (2009). Decreases in Shark Catches and Mortality in the Hawaii-Based Longline Fishery as Documented by Fishery Observers. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 2009*(2009), 270-282 https://doi.org/10.1577/C09-003.1

This article summarizes catch data for sharks collected by fishery observers during two periods (1995–2000 and 2004–2006) in the Hawaii-based pelagic longline fishery, which targets swordfish *Xiphias gladius* in the shallow-set sector and bigeye tuna *Thunnus obesus* in the deep-set sector. The blue shark *Prionace glauca* was the predominant shark species caught throughout the study period (84.5% of all sharks). Five other species (bigeye thresher *Alopias superciliosus*, oceanic whitetip shark *Carcharhinus longimanus*, shortfin mako *Isurus oxyrinchus*, silky shark C. falciformis, and crocodile shark Pseudocarcharias kamoharai) were relatively common (1.0–4.1%). Two major developments affected shark catches in this fishery during the study period. The first was the prohibition in 2000 of shark finning under most circumstances. The second development was that management measures were taken in 2000 and 2001 to protect sea turtles (leatherback sea turtles Dermochelys coriacea and loggerhead sea turtles *Caretta caretta*) and these measures included a closure of the shallow-set (swordfish-targeting) sector for more than 3 years. The closure caused decreases in shark catches because the shallow-set sector was typically characterized by high catch rates. The shallow-set sector was reopened in 2004. Comparisons of nominal catch per unit effort (number of sharks/1,000 hooks) revealed significant differences in catch rates between the two fishery sectors and the two periods. Blue shark and shortfin mako catch rates were significantly greater in the shallow-set sector than in the deep-set sector of the fishery, whereas the opposite was true for the deeper-dwelling bigeye threshers and crocodile sharks. Catch rates for the blue shark, oceanic whitetip shark, bigeye thresher, and crocodile shark were significantly lower in 2004–2006 than in 1995–2000. For the blue shark in particular, the combination of reduced catch rates, the finning ban, and an apparent capacity to resist the stress of capture on longline gear resulted in low (4%–5.7%) minimum mortality estimates. Therefore, we conclude that the Hawaii-based pelagic longline fishery has made substantial progress in reducing shark mortality.

Wu, X.-H., Liu, S. Y. V., Wang, S.-P., & Tsai, W.-P. (2021). Distribution Patterns and Relative Abundance of Shortfin Mako Shark Caught by the Taiwanese Large-Scale Longline Fishery in the Indian Ocean. *Regional Studies in Marine Science, 44*, 101691 https://doi.org/10.1016/j.rsma.2021.101691

The shortfin mako shark, *Isurus oxyrinchus*, is one of the most common bycatch species of the Taiwanese tuna longline fishery (Taiwan was second-largest shortfin mako shark-catching nation) in the Indian Ocean. The present study estimated the distribution and relative abundance indices of the shortfin mako in the Indian Ocean using observer records and logbook data from the period 2005–2018. To deal with the high number of zero catch records (~90%), the catch per unit effort (CPUE) was standardized using a Zero inflated negative binomial model (ZINB). Cluster analysis was used to identify the fishing operations associated with different fishing strategies and then incorporated as a factor related to target species into the ZINB. Considerable variation was observed in the size distribution by region and season in the Indian ocean. Larger mako sharks (age>15 and age>7 yr for female and male, respectively) tend to occur in equatorial and tropical regions, while smaller specimens appear at higher

latitudes in temperate waters. Cluster analysis produced five fishing clusters based on the catch compositions of the main species. The target factor (cluster) was important in explaining the variance in ZINB models. Overall, the standardized CPUEs and nominal CPUEs analysis for the shortfin mako caught by the Taiwanese longline fishery indicates a stable and increasing trend in recent years.

Yokoi, H., Ijima, H., Ohshimo, S., & Yokawa, K. (2017). Impact of Biology Knowledge on the Conservation and Management of Large Pelagic Sharks. *Scientific Reports, 7* https://doi.org/10.1038/s41598-017-09427-3

Population growth rate, which depends on several biological parameters, is valuable information for the conservation and management of pelagic sharks, such as blue and shortfin mako sharks. However, reported biological parameters for estimating the population growth rates of these sharks differ by sex and display large variability. To estimate the appropriate population growth rate and clarify relationships between growth rate and relevant biological parameters, we developed a two-sex age-structured matrix population model and estimated the population growth rate using combinations of biological parameters. We addressed elasticity analysis and clarified the population growth rate sensitivity. For the blue shark, the estimated median population growth rate was 0.384 with a range of minimum and maximum values of 0.195-0.533, whereas those values of the shortfin mako shark were 0.102 and 0.007-0.318, respectively. The maturity age of male sharks had the largest impact for blue sharks, whereas that of female sharks had the largest impact for shortfin mako sharks. Hypotheses for the survival process of sharks also had a large impact on the population growth rate estimation. Both shark maturity age and survival rate were based on ageing validation data, indicating the importance of validating the quality of these data for the conservation and management of large pelagic sharks.

Zhu, J., Dai, X., & Chen, Y. (2013). Productivity-Susceptibility Analysis of 10 Shark Populations in Tropical Pacific Ocean. *South China Fisheries Science, 9*(6), 8-13 https://doi.org/10.3969/j.issn.2095-0780.2013.06.002

The tropical Pacific Ocean is the main tuna fishing area in the world. The impact of tuna longline fishery on pelagic shark populations has received considerable concerns recently. However, it is difficult to evaluate their population status using formal stock assessment models due to the lack of long-term fishery data. We conduct productivity-susceptibility analysis (PSA) to evaluate the vulnerability to overfishing for 10 pelagic shark species in the tropical Pacific Ocean. The 10 species with risk of overfishing suffered from longline fishery, in terms of vulnerability score, are as follows (in ascending order): smooth hammerhead (Sphyma zygaena) , scalloped hammerhead (S. lewini), great hammerhead (S. mokarran), shortfin mako (*Isurus oxyrinchus*), common thresher (*Alopias vulpinus*), oceanic whitetip shark (*Carcharhinus longimanus*), blue shark (*Prionace glauca*), silky shark (C. falciformis), pelagic thresher (A. pelagicus) and bigeye thresher (A. supercuiosus). The results provide important information for conservation of pelagic sharks and pelagic ecosystem interacting with tuna longline fisheries in the tropical Pacific Ocean.

Section V: Threats

Alves, L. M. F., Correia, J. P. S., Lemos, M. F. L., Novais, S. C., & Cabral, H. (2020). Assessment of Trends in the Portuguese Elasmobranch Commercial Landings over Three Decades (1986-2017). *Fisheries Research, 230*, 105648 https://doi.org/10.1016/j.fishres.2020.105648

Portugal plays a major role in shark, skate and ray fisheries in the European Union. With the decline of these animals raising concerns amongst scientists all over the world, we set out to provide an updated assessment on elasmobranch landings in Portugal between 1986 and 2017. The dataset analysed in this study consisted of 15,521 records, each with information concerning the species (or higher taxonomic level), port, month, year, and weight of fish landed. A non-parametric change points assessment statistical technique was used to evaluate important changes in landings throughout the time series. Principal components analysis was also performed to mean values of landings per year for the most captured species, and similar analysis was conducted using fishing ports instead of year, for the same sub-set of species / taxa. According to the data, more than 143 thousand metric tons of elasmobranchs were landed in Portuguese ports between 1986 and 2017, divided by 58 taxa of sharks, skates and rays. The most landed taxa were demersal rays and skates (Raja spp.), followed by spotted dogfishes (Scyliorhinus spp.), blue shark (*Prionace glauca*), Portuguese dogfish (Centroscymnus coelolepis), leafscale gulper shark (Centrophorus squamosus), gulper shark (Centrophorus granulosus) and shortfin mako (*Isurus oxyrinchus*). Together, these seven taxa accounted for more than 75% of all landings. Several cases of misreporting were identified and discussed. Overall, landings of elasmobranchs in Portugal show marked decreases and changes in composition, with deep-sea sharks being the most influential group during the studied period.

Ankhelyi, M. V., Wainwright, D. K., & Lauder, G. V. (2018). Diversity of Dermal Denticle Structure in Sharks: Skin Surface Roughness and Three-Dimensional Morphology. *J Morphol, 279*(8), 1132-1154 https://doi.org/10.1002/jmor.20836

Shark skin is covered with numerous placoid scales or dermal denticles. While previous research has used scanning electron microscopy and histology to demonstrate that denticles vary both around the body of a shark and among species, no previous study has quantified three-dimensional (3D) denticle structure and surface roughness to provide a quantitative analysis of skin surface texture. We quantified differences in denticle shape and size on the skin of three individual smooth dogfish sharks (Mustelus canis) using micro-CT scanning, gel-based surface profilometry, and histology. On each smooth dogfish, we imaged between 8 and 20 distinct areas on the body and fins, and obtained further comparative skin surface data from leopard, Atlantic sharpnose, shortfin mako, spiny dogfish, gulper, angel, and white sharks. We generated 3D images of individual denticles and measured denticle volume, surface area, and crown angle from the micro-CT scans. Surface profilometry was used to quantify metrology variables such as roughness, skew, kurtosis, and the height and spacing of surface features. These measurements confirmed that denticles on different body areas of smooth dogfish varied widely in size, shape, and spacing. Denticles near the snout are smooth, paver-like, and large relative to denticles on the body. Body denticles on smooth dogfish generally have between one and three distinct ridges, a diamond-like surface shape, and a dorsoventral gradient in spacing and roughness. Ridges were spaced on average 56 microm apart, and had a mean height of 6.5 microm, comparable to denticles from shortfin mako sharks, and with narrower spacing and lower heights than other species measured. We observed considerable variation in denticle structure among regions on the pectoral, dorsal, and caudal

fins, including a leading-to-trailing edge gradient in roughness for each region. Surface roughness in smooth dogfish varied around the body from 3 to 42 microns.

Báez, J. C. (2015). Assessing the Influence of the Atmospheric Oscillations on Pelagic and Highly Migratory Sharks Bycatches from Spanish Mediterranean Sea, a Meta-Analytic Approach. *Anales de Biología*(37), 31 https://doi.org/10.6018/analesbio.37.4

Blue shark, shortfin mako shark and the thresher sharks are the three taxa of pelagic sharks most caught as bycatch in the Spanish pelagic longline fishery from Mediterranean Sea. The main aim of the present study was to analyse the effect of atmospheric oscillations about landing patterns of blue shark, shortfin mako shark, and thresher sharks from Spanish Mediterranean Sea, using a metaanalytical approach. The ultimate goal was to understand the response of highly migratory sharks to large-scale climate phenomena, and its possible link with the effect of global warming. Two different data sources were used from different geographical areas: Alboran Sea and Balearic Sea. The results indicate that the local abundance of pelagic sharks could be mediated by the Arctic Oscillation.

Baibbat, S., Serghini, M., Abid, N., Ikkiss, A., Joundoul, S., & Houssa, R. (2020). Shortfin Mako (*Isurus oxyrinchus*) Fishery in the South of the Moroccan Atlantic Waters. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 76*(10), 115-128 Retrieved from https://www.bmis-bycatch.org/system/files/zotero_attachments/library_1/T9FURWCQ%20-%20Baibbat%20et%20al.%20-%20SHORFIN%20MAKO%20%28ISURUS%20OXYRINCHUS%29%20BY-CATCH%20FISHERY%20.pdf

The shortfin mako is a species caught mainly as by-catch by Moroccan longliners targeting swordfish in the south of the Moroccan Atlantic waters. A series of catch and individual weight data were analyzed in order to derive the exploitation indicators for this species.

Barreto, R., Bornatowski, H., Fiedler, F. N., Pontalti, M., da Costa, K. J., Nascimento, C., & Kotas, J. E. (2019). Macro-Debris Ingestion and Entanglement by Blue Sharks (*Prionace glauca* Linnaeus, 1758) in the Temperate South Atlantic Ocean. *Marine Pollution Bulletin, 145*, 214-218 https://doi.org/10.1016/j.marpolbul.2019.05.025

No abstract.

Beerkircher, L. R. (2005). Characteristics of Blue, *Prionace glauca*, and Shortfin Mako, *Isurus oxyrinchus*, Shark by Catch Observed on Pelagic Longlines in the Northwest Atlantic, 1992-2003. *ICCAT Col. Vol. Sci. Pap, 58*(3), 1019-1033 Retrieved from http://flyingsharks.eu/literature/iccat/CV058031019.pdf

From May 1992 to December 2003, scientific observers from the National Marine Fisheries Service's (NMFS) Miami Laboratory documented 7,226 hauls of U.S. pelagic longline vessels operating in the northwestern Atlantic. Observers recorded the bycatch of 55681 blue, *Prionace glauca*, and 2897 shortfin mako, *Isurus oxyrinchus*, sharks. Eighty percent of blue sharks and 69% of mako sharks were

alive on gear retrieval. Over 75 % of blue sharks were released alive; 61 % of mako sharks were retained and at least 23 % were released alive. Mean fork lengths for blue sharks ranged from 140 cm FL in the northeast distant (NED) spatial area to 207 cm FL in the tuna north-tuna south (TUN/TUS) area; for mako sharks, the range was 133 cm FL in the NED to 210 cm FL in the Caribbean (CAR). Length frequencies and sex ratios by spatial strata are presented for both species. Nominal catch per unit effort (CPUE) for both species was highest in the NED. Bootstrap procedures were used to estimate yearly mean CPUE and 95% confidence limits for various spatial strata. Results should be interpreted while taking into account seasonal patterns of fishing effort, changes in fishing techniques over the time period, and potential observer error.

Beerkircher, L. R., Cortes, E., & Shivji, M. (2002). Characteristics of Shark Bycatch Observed on Pelagic Longlines Off the Southeastern United States, 1992-2000. *Marine Fisheries Review, 64*(4), 40-49 Retrieved from https://spo.nmfs.noaa.gov/content/characteristics-shark-bycatch-observed-pelagic-longlines-southeastern-united-states-1992

Data collected by fisheries observers aboard U.S. pelagic longline vessels were examined to quantify and describe elasmobranch bycatch off the southeastern U.S. coast (lat. 22 degree -35 degree N, long. 71 degree -82 degree W). From 1992 to 2000, 961 individual longline hauls were observed, during which 4,612 elasmobranchs (15% of the total catch) were documented. Of the 22 elasmobranch species observed, silky sharks, *Carcharhinus falciformis*, were numerically dominant (31.4% of the elasmobranch catch). The catch status of the animals (alive or dead) when the gear was retrieved varied widely depending on the species, with high mortalities seen for the commonly caught silky and night, C. signatus, sharks and low mortalities for rays (Dasyatidae and Mobulidae), blue, *Prionace glauca*; and tiger, *Galeocerdo cuvier*; sharks. Discard percentages also varied, ranging from low discards (27.6%) for shortfin mako, *Isurus oxyrinchus*, to high discards for blue (99.8%), tiger (98.5%), and rays (100%). Mean fork lengths indicated the majority of the observed bycatch -- regardless of species -- was immature, and significant quarterly variation in fork length was found for several species including silky; dusky, *C. obscurus*; night; scalloped hammerhead, *Sphyrna lewini*; oceanic whitetip, *C. longimanus*; and sandbar, *C. plumbeus*; sharks. While sex ratios overall were relatively even, blue, tiger, and scalloped hammerhead shark catches were heavily dominated by females. Bootstrap methods were used to generate yearly mean catch rates (catch per unit effort) and 95% confidence limits; catch rates were generally variable for most species, although regression analysis indicated significant trends for night, oceanic whitetip, and sandbar sharks. Analysis of variance indicated significant catch rate differences among quarters for silky, dusky, night, blue, oceanic whitetip, sandbar, and shortfin mako sharks.

Benz, G. W. (1980). Tissue Proliferations Associated with Nemesis Lamna Risso, 1826 (Copepoda: Eudactylinidae) Infestations on the Gill Filaments of Shortfin Makos (*Isurus oxyrinchus* Rafinesque)*. *Journal of Fish Diseases, 3*(5), 443-446 https://doi.org/10.1111/j.1365-2761.1980.tb00429.x

No abstract.

Benz, G. W., Borucinska, J. D., & Greenwald, S. A. (2002). First Descriptions of Early- and Middle-Stage Copepodids of Anthosoma Crassum (Dichelesthiidae: Siphonostomatoida) and Lesions on Shortfin Makos (*Isurus oxyrinchus*) Infected with A. Crassum. *Journal of Parasitology, 88*(1), 19-26 https://doi.org/10.1645/0022-3395(2002)088[0019:Fdoeam]2.0.Co;2

Early- and middle-stage copepodids of *Anthosoma crassum* (Dichelesthiidae: Siphonostomatoida) and lesions associated with *A. crassum* infections are described from samples collected from the jaws of shortfin makos captured off southern California. The copepodids did not possess frontal filaments or frontal organs, and they resided in a headstandlike position firmly attached by their embedded antennae. Copepod larvae and small adults were lodged in shallow mucosal ulcers that basally exhibited mild, acute granulocytic stomatitis; large adults were lodged in deep tunnels encompassing the anterior aspects of their bodies. Some lesions contained more than 1 copepod. Examinations of lesions revealed that A. crassum infection of shortfin makos can result in severe subacute, necrotizing stomatitis with hemorrhage, granulation tissue, and lymphocytic aggregations in the mucosa, and reactive lymphocytic infiltration of the submucosal skeletal muscle. Copepod gut contents consisted of shark erythrocytes, hemosiderin granules, and necrotic host cells. These observations, along with reports of sharks heavily infected with A. crassum, suggest that this copepod may sometimes play a role in the morbidity and mortality of sharks that it infects.

Birkmanis, C. A., Partridge, J. C., Simmons, L. W., Heupel, M. R., & Sequeira, A. M. M. (2020). Shark Conservation Hindered by Lack of Habitat Protection. *Global Ecology and Conservation, 21* https://doi.org/10.1016/j.gecco.2019.e00862

Many of the world's shark populations are in decline, indicating the need for improved conservation and management. Well managed and appropriately located marine parks and marine protected areas (MPAs) have potential to enhance shark conservation by restricting fisheries and protecting suitable habitat for threatened shark populations. Here, we used shark occurrence records collected by commercial fisheries to determine suitable habitat for pelagic sharks within the Australian continental Exclusive Economic Zone (EEZ), and to quantify the amount of suitable habitat contained within existing MPAs. We developed generalised linear models using proportional occurrences of pelagic sharks for three families: Alopiidae (thresher), Carcharhinidae (requiem), and Lamnidae (mackerel) sharks. We also considered aggregated species from the Lamnidae and Carcharhinidae families ('combined sharks' in the models). Using a set of environmental predictors known to affect shark occurrence, including chlorophyll-a concentration, salinity, sea surface temperature, and turbidity, as well as geomorphological, geophysical, and sedimentary parameters, we found that models including sea surface temperature and turbidity were ranked highest in their ability to predict shark distributions. We used these results to predict geographic regions where habitat was most suitable for pelagic sharks within the Australian EEZ, and our results revealed that suitable habitat was limited in no-take zones within MPAs. For all shark groupings, suitable habitats were found mostly at locations exposed to fishing pressure, potentially increasing the vulnerability of the pelagic shark species considered. Our predictive models provide a foundation for future spatial planning and shark management, suggesting that strong fisheries management in addition to MPAs is necessary for pelagic shark conservation.

Biton-Porsmoguer, S. (2018). Intensive Exploitation of Blue Shark *Prionace glauca* and Shortfin Mako *Isurus oxyrinchus*: Analysis of the Fisheries in the North-Eastern Atlantic Ocean from 2001 to

2016. *Revista De Biologia Marina Y Oceanografia, 53*(1), 27-38 https://doi.org/10.4067/S0718-19572018000100027

Blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) are species exploited by the Spanish and Portuguese longline fleet. They land sharks in the fish market at Vigo (Spain). The number of longliners decreased between 2004 and 2016 (less 15 boats). Landings of shortfin mako have decreased and those of blue shark increased between 2001 and 2016. In accordance with ICCAT informs, the blue shark stock is not overexploited. But it is for shortfin mako in the North-eastern Atlantic Ocean. The sharks landed in a fish market are mainly juvenile, the maturity age being late for both species. The authorities must establish measures to reduce fishing pressure.

Bornatowski, H., Braga, R. R., & Vitule, J. R. (2013). Shark Mislabeling Threatens Biodiversity. *Science, 340*(6135), 923 https://doi.org/10.1126/science.340.6135.923-a

No abstract.

Borucinska, J. D., Kotran, K., Shackett, M., & Barker, T. (2009). Melanomacrophages in Three Species of Free-Ranging Sharks from the Northwestern Atlantic, the Blue Shark Prionacae Glauca (L.), the Shortfin Mako, Isurus Oxyrhinchus Rafinesque, and the Thresher, *Alopias vulpinus* (Bonnaterre). *J Fish Dis, 32*(10), 883-891 https://doi.org/10.1111/j.1365-2761.2009.01067.x

The melanomacrophage aggregates or cells (MMC) are commonly used as biomarkers of exposure to pollution in fish, albeit their numbers and morphological characteristics can be influenced not only by environmental toxins but also by a range of physiological parameters and pathological conditions. Accordingly, before we can use MMC as biomarkers in any fish species, their normal, 'background' characteristics have to be established in apparently healthy fish. The knowledge of MMC in sharks is minimal. The aim of this study was to characterize MMC from 51 free-ranging, large pelagic sharks from the northwestern Atlantic, including shortfin mako, *Isurus oxyrhinchus*, thresher, *Alopias vulpinus* and blue shark, *Prionacae glauca*. The rationale of this study was twofold. First, because, sharks have life histories predisposing them to the accumulation of environmental toxins they constitute good sentinel species of the health of the global marine ecosystem. Second, because many shark populations are in decline or threatened by extinction, we need to expand our understanding of their health status in order to develop appropriate protective measures. All sharks were collected by sports fishing gear between June and August in 2007. Their health condition was assessed by necropsy, morphometrics, and by microscopic examination of gonads, livers, spleens and kidneys. Routine, haematoxylin and eosin and/or Pearl's reagent-stained paraffin embedded sections were studied by light microscopy. Our results provide the first data on the morphometric and morphological characteristics of MMC in viscera of apparently healthy free-ranging sharks from the northwestern Atlantic.

Bowlby, H. D., Benoit, H. P., Joyce, W., Sulikowski, J., Coelho, R., Domingo, A., . . . Anderson, B. (2021). Beyond Post-Release Mortality: Inferences on Recovery Periods and Natural Mortality from Electronic Tagging Data for Discarded Lamnid Sharks. *Frontiers in Marine Science, 8* https://doi.org/10.3389/fmars.2021.619190

Accurately characterizing the biology of a pelagic shark species is critical when assessing its status and resilience to fishing pressure. Natural mortality (M) is well known to be a key parameter determining productivity and resilience, but also one for which estimates are most uncertain. While M can be inferred from life history, validated direct estimates are extremely rare for sharks. Porbeagle (*Lamna nasus*) and shortfin mako (*Isurus oxyrinchus*) are presently overfished in the North Atlantic, but there are no directed fisheries and successful live release of bycatch is believed to have increased. Understanding M, post-release mortality (PRM), and variables that affect mortality are necessary for management and effective bycatch mitigation. From 177 deployments of archival satellite tags, we inferred mortality events, characterized physiological recovery periods following release, and applied survival mixture models to assess M and PRM. We also evaluated covariate effects on the duration of any recovery period and PRM to inform mitigation. Although large sample sizes involving extended monitoring periods (>90 days) would be optimal to directly estimate M from survival data, it was possible to constrain estimates and infer probable values for both species. Furthermore, the consistency of M estimates with values derived from longevity information suggests that age determination is relatively accurate for these species. Regarding bycatch mitigation, our analyses suggest that juvenile porbeagle are more susceptible to harm during capture and handling, that keeping lamnid sharks in the water during release is optimal, and that circle hooks are associated with longer recovery periods for shortfin mako.

Brunnschweiler, J. M., Nielsen, F., & Motta, P. (2011). In Situ Observation of Stomach Eversion in a Line-Caught Shortfin Mako (*Isurus oxyrinchus*). *Fisheries Research, 109*(1), 212-216 https://doi.org/10.1016/j.fishres.2011.02.005

The Shortfin Mako, *Isurus oxyrinchus*, has the ability to evert and retract its cardiac stomach out of the mouth when caught on a line, and presumably also under more natural conditions. Using video of a live caught Shortfin Mako and manual manipulation of a specimen, observations of the intestinal anatomy were made during eversion, and a putative mechanism for gastric eversion proposed. Stomach eversion in the line-caught Shortfin Mako was extremely rapid with parts of the cardiac portion of the stomach being everted for similar to 0.33 s. The stomach of the Shortfin Mako is composed of a long pyloric region folded back upon the cardiac region, with the two regions being united by a wide and somewhat stretchy hepatogastric ligament. The stomach and anterior intestine is united to the dorsal body wall by the mesogaster at the very anterior region above the anterior margin of the liver. Anterior travel of the intestine is therefore not limited by its attachment of the mesogaster to the dorsal body wall, and the unfolding of the cardiac region on the long pyloric region facilitates its forward movement. The anterior movement of the everted cardiac stomach appears to be limited by the posterior attachment and length of the spiral valve intestine. A mechanism for eversion and retraction is proposed, with eversion being due to anterior propulsion of the gut due to contraction of lateral abdominal muscles, elevation of the pharyngeal region, and retropulsive waves of contraction of the stomach. Retraction of the everted stomach may be due to a suction event similar to suction feeding and suction transport in elasmobranchs, combined with a peristaltic wave of contraction from the esophagus through the cardiac region of the stomach.

Caira, J. N., & Bardos, T. (1996). Further Information on Gymnorhynchus Isuri (Trypanorhyncha: Gymnorhynchidae) from the Shortfin Mako Shark. *Journal of the Helminthological Society of Washington, 63*(2), 188-192 Retrieved from http://bionames.org/bionames-archive/issn/1049-233X/63/188.pdf

The morphology of the mature segments of *Gymnorhynchus isuri* Robinson, 1959, is described for the first time from specimens collected from shortfin mako sharks at Montauk, Long Island, New York. This species was found to possess a muscular cirrus sac with a conspicuous external seminal vesicle but no accessory seminal vesicle. It possesses an ovary that is tetralobed in cross-section, a uterus that is porally deviated and circumcortical vitellaria that are external to the longitudinal muscle bundles of the segment. Scanning electron microscopy of the scolex reveals that all types of microtriches are conspicuously absent from all regions of the scolex with the exception of the distal bothridial surfaces, which bear densely packed, filiform microtriches. The diagnosis of the genus Gymnorhynchus and family Gymnorhynchidae are emended to reflect these new data.

Caira, J. N., Benz, G. W., Borucinska, J., & Kohler, N. E. (1997). Pugnose Eels, Simenchelys Parasiticus (Synaphobranchidae) from the Heart of a Shortfin Mako, *Isurus oxyrinchus* (Lamnidae). *Environmental Biology of Fishes, 49*(1), 139-144 https://doi.org/10.1023/A:1007398609346

A 395 kg shortfin mako, *Isurus oxyrinchus* (Lamnidae) landed at Montauk, New York in June of 1992 was found to contain two dead, but otherwise healthy appearing pugnose eels, Simenchelys parasiticus (Synaphobranchidae) within the lumen of its heart. The path along which the eels made their way into the shark's heart was not found. Histological examination of the shark's heart revealed the presence of medial hyperplasia and hypertrophy of small arterioles, multifocal arteriosclerosis, and relatively high numbers of capillaries per unit area. These phenomena were not observed in similar sections taken from hearts of six uninfected mako sharks. The stomachs of both eels were filled with blood, suggesting that they had been within the shark at least long enough to feed. Consideration of this new record along with the literature supports a trophic designation of facultative endoparasite for the species Simenchelys parasiticus.

Campana, S. E. (2016). Transboundary Movements, Unmonitored Fishing Mortality, and Ineffective International Fisheries Management Pose Risks for Pelagic Sharks in the Northwest Atlantic. *Canadian Journal of Fisheries and Aquatic Sciences, 73*(10), 1599-1607 https://doi.org/10.1139/cjfas-2015-0502

The shortfin mako (*Isurus oxyrinchus*), porbeagle (*Lamna nasus*), and blue shark (*Prionace glauca*) are three frequently caught shark species in the northwestern Atlantic Ocean. Satellite tagging studies show that all three species range widely across many national boundaries but spend up to 92% of their time on the high seas, where they are largely unregulated and unmonitored. All are caught in large numbers by swordfish and tuna fishing fleets from a large number of nations, usually unintentionally, and all are unproductive by fish standards, which makes them particularly sensitive to fishing pressure. Landing statistics that grossly underrepresent actual catches, unreported discards that often exceed landings, and high discard mortality rates are threats to the populations and roadblocks to useful population monitoring. The influence of these threats is greatly magnified by inattention and ineffective management from the responsible management agency, the International Commission for the Conservation of Atlantic Tunas (ICCAT), whose prime focus is the more valuable swordfish and tuna stocks. Although practical management options are available, none will be possible if organizations like ICCAT continue to treat sharks like pests.

Campana, S. E., Joyce, W., Fowler, M., & Showell, M. (2016). Discards, Hooking, and Post-Release Mortality of Porbeagle (*Lamna nasus*), Shortfin Mako (*Isurus oxyrinchus*), and Blue Shark (*Prionace glauca*) in the Canadian Pelagic Longline Fishery. *ICES Journal of Marine Science, 73*(2), 520-528 https://doi.org/10.1093/icesjms/fsv234

Global discards of sharks greatly exceed reported landings, yet there are few estimates of mortality after release. Based on more than 21 000 fisheries observer records and the results of 109 popup satellite archival tags, all sources of fishing-induced mortality (harvest, capture, and post-release) were estimated for blue sharks (*Prionace glauca*), shortfin mako(*Isurus oxyrinchus*), and porbeagle (*Lamna nasus*) in the Canadian pelagic longline fishery between 2010 and 2014. Hooking mortality ranged from 15 to 44%, with porbeagles and makos experiencing much greater mortality than blue sharks. The post-release mortality rate varied between 10 and 31%, with porbeagle and mako again having the highest mortality rate. Overall, about one-half of the hooked porbeagles and makos died during or after fishing, with most of the post-release mortality occurring within 2 d of release. Landed catch accounted for less mortality in porbeagle and blue sharks than did the combination of hooking and post-release mortality. These results indicate that the conservation benefits of mandatory release regulations for pelagic longline gear are not nearly as great as is now assumed.

Cardenosa, D., Fields, A. T., Babcock, E. A., Shea, S. K. H., Feldheim, K. A., & Chapman, D. D. (2020). Species Composition of the Largest Shark Fin Retail-Market in Mainland China. *Sci Rep, 10*(1), 12914 https://doi.org/10.1038/s41598-020-69555-1

Species-specific monitoring through large shark fin market surveys has been a valuable data source to estimate global catches and international shark fin trade dynamics. Hong Kong and Guangzhou, mainland China, are the largest shark fin markets and consumption centers in the world. We used molecular identification protocols on randomly collected processed fin trimmings (n = 2000) and non-parametric species estimators to investigate the species composition of the Guangzhou retail market and compare the species diversity between the Guangzhou and Hong Kong shark fin retail markets. Species diversity was similar between both trade hubs with a small subset of species dominating the composition. The blue shark (*Prionace glauca*) was the most common species overall followed by the CITES-listed silky shark (*Carcharhinus falciformis*), scalloped hammerhead shark (*Sphyrna lewini*), smooth hammerhead shark (*S. zygaena*) and shortfin mako shark (*Isurus oxyrinchus*). Our results support previous indications of high connectivity between the shark fin markets of Hong Kong and mainland China and suggest that systematic studies of other fin trade hubs within Mainland China and stronger law-enforcement protocols and capacity building are needed.

Carvalho, F. (2021). *Standardized Catch Rates of Shortfin Mako Shark (Isurus oxyrinchus) Caught by the Hawaii-Based Pelagic Longline Fleet (1995-2019)*. Paper presented at the ISC/21/SHARKWG-1. Webinar Retrieved from http://isc.fra.go.jp/reports/shark/shark_2021_1.html

Catch and effort data from the Hawaii-based pelagic longline fishery operating in the North Pacific Ocean were analyzed to estimate indices of abundance for the shortfin mako shark between 1995 and 2019. The data come from the records of the Pacific Islands Regional Observer Program (PIROP) submitted to the Pacific Islands Fisheries Science Center (PIFSC). Nominal CPUEs were calculated separately for shallow-set (target: swordfish) and deep-set (target: bigeye tuna) sectors, and standardized with Generalized Linear Models (GLM), separately for each sector. Model validation was

carried out with residual analysis. The best-fit models included variables year, quarter of the year, region, sea surface temperature, bait type, and interactions between quarter of the year and region. Overall, the standardized CPUE for the deep-set sector showed a stable trend from 1995 to 2016, followed by an increase in the last three years, while the standardized CPUE in shallow-set sector showed a slightly decrease up to 2012, followed by an increase in 2013.

Celona, A., Donato, N., & Maddalena, A. (2001). In Relation to the Captures of a Great White Shark, *Carcharodon carcharias* (Linnaeus, 1758), and a Shortfin Mako, *Isurus oxyrinchus* Rafinesque, 1809, in the Messina Strait. *Annales, Series Historia Naturalis,, 11*(1), 13-16 Retrieved from https://zdjp.si/en/p/annalesshn/page/5/

A critical revision of some incorrect data recently reported by Fergusson et al. (2000) in relation to the two captures of sharks in the waters near Gazirri (Messina Strait, Italy) and their stomach contents is given. A specimen caught in 1963, reported by Fergusson et al. (2000) as a white shark *Carcharodon carcharias* having in its stomach a marine turtle *Caretta caretta*, was in fact a shortfin mako *Isurus oxyrinchus* having in the stomach a bow-net and some buttons. The other, a white shark caught in 1965, had in its stomach remains of marine turtle C. caretta, and not an ocean sunfish Mola mola as erroneously reported by Fergusson et al. (2000).

Clarke, S. C., Magnussen, J. E., Abercrombie, D. L., McAllister, M. K., & Shivji, M. S. (2006). Identification of Shark Species Composition and Proportion in the Hong Kong Shark Fin Market Based on Molecular Genetics and Trade Records. *Conservation Biology, 20*(1), 201-211 https://doi.org/10.1111/j.1523-1739.2005.00247.x

The burgeoning and largely unregulated trade in shark fins represents one of the most serious threats to shark populations worldwide. In Hong Kong, the world's largest shark fin market, fins are classified by traders into Chinese-name categories on the basis of market value, but the relationship between market category and shark species is unclear preventing identification of species that are the most heavily traded. To delineate these relationships, we designed a sampling strategy for collecting statistically sufficient numbers of fins from traders and categories under conditions of limited market access because of heightened trader sensitivities. Based on information from traders and morphological inspection, we hypothesized matches between market names and shark taxa for fins within 11 common trade categories. These hypotheses were tested using DNA-based species identification techniques to determine the concordance between market category and species. Only 14 species made up approximately 40% of the auctioned fin weight. The proportion of samples confirming the hypothesized match, or concordance, varied from 0.64 to 1 across the market categories. We incorporated the concordance information and available market auction records for these categories into stochastic models to estimate the contribution of each taxon by weight to the fin trade. Auctioned fin weight was dominated by the blue shark (*Prionace glauca*), which was 17% of the overall market. Other taxa, including the shortfin mako (*Isurus oxyrinchus*), silky (*Carcharhinus falciformis*), sandbar (C. obscurus), bull (*C. leucas*), hammerhead (*Sphyrna spp*.), and thresher (*Alopias spp*.), were at least 2-6% of the trade. Our approach to marketplace monitoring of wildlife products isparticularly applicable to situations in which quantitative data at the source of resource extraction are sparse and large-scale genetic testing is limited by budgetary or other market access constraints.

Cliff, G., Dudley, S. F. J., & Davis, B. (1990). Sharks Caught in the Protective Gill Nets Off Natal, South-Africa .3. The Shortfin Mako Shark Isurus-Oxyrinchus (Rafinesque). *South African Journal of Marine Science-Suid-Afrikaanse Tydskrif Vir Seewetenskap, 9*, 115-126 https://doi.org/10.2989/025776190784378808

Between 1966 and 1989, 255 shortfin mako sharks *Isurus oxyrinchus* were caught in the gill nets which protect the tourist beaches of Natal. The catch rate showed no trend, fluctuating about a mean of 0,34 sharks km-net-1 year 1 female. Specimens ranged in size from 84 to 276 cm precaudal length, with a mode of 191-195 cm for males and 251-255 cm for females. Males matured at 160-170 cm and females at approximately 220 cm. Catches included two recently fertilized females and two with well-developed males examined and 41 per cent of females. Elasmobranchs were the most common prey category, occuring in 60 sharks shorter than 1 m.

Coelho, R., Fernandez-Carvalho, J., Lino, P. G., & Santos, M. N. (2012). An Overview of the Hooking Mortality of Elasmobranchs Caught in a Swordfish Pelagic Longline Fishery in the Atlantic Ocean. *Aquatic Living Resources, 25*(4), 311-319 https://doi.org/10.1051/alr/2012030

Hooking (or "at-haulback") fishing mortality was analysed in elasmobranchs captured by Portuguese longliners targeting swordfish in the Atlantic Ocean. Information was collected by on-board fishery observers who monitored 834 longline fishing sets between August 2008 and December 2011, and recorded information on 36 067 elasmo-branch specimens from 21 different taxa. The hooking mortality proportions were species-specific, with some species having relatively high percentages of live specimens at time of haulback (e. g., blue shark, crocodile shark, pelagic stingray, manta, devil and eagle rays), while others had higher percentages of dead specimens (e. g., smooth hammerhead, silky shark, bigeye thresher). For the most captured species (*Prionace glauca*, *Pseudocarcharias kamoharai*, *Isurus oxyrinchus* and *Alopias superciliosus*), logistic generalized linear models (GLMs) were carried out to compare the mortality rates between sexes, specimen sizes and the regions of operation of the fleet. The sex-specific proportions of hooking mortality were significantly different for blue and crocodile sharks, with the males of both species having higher proportions of hooking mortality than the females. Specimen size was significant for predicting the hooking mortality for blue and shortfin mako sharks: in both cases, the larger specimens had lower odds of dying due to the fishing process. There were differences in the hooking mortality depending on the region of operation of the fleet, but those differences were also species-specific. For blue and crocodile sharks, the hooking mortality was higher in the Equatorial and southern Atlantic areas (when compared to the NE Atlantic region), while the opposite was observed for the shortfin mako, with lower mortality rates in the NE tropical area compared with the other regions. The results presented in this paper can be integrated into future ecological risk assessment analysis for pelagic elasmobranchs. Furthermore, the new information can be used to evaluate the impact of recent recommendations prohibiting the retention of some vulnerable elasmobranch species.

Dinkel, T. M., & Sanchez-Lizaso, J. L. (2020). Involving Stakeholders in the Evaluation of Management Strategies for Shortfin Mako (*Isurus oxyrinchus*) and Blue Shark (*Prionace glauca*) in the Spanish Longline Fisheries Operating in the Atlantic Ocean. *Marine Policy, 120* https://doi.org/10.1016/j.marpol.2020.104124

Shortfin mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*) are a relevant bycatch in the Spanish surface longline fisheries that operate in the Atlantic Ocean. Concern has been raised after the 2017 and 2019 shortfin mako evaluations for the Northern Atlantic stock. It stated the population being overfished and suffering from overfishing. Also blue shark is subject to high extraction rates in the Atlantic Ocean. Few data and uncertainty in assessment results suggest that further management strategies could be taken into account for both species. This study evaluated different fisheries management strategies for shortfin mako and blue shark in the Atlantic Ocean from the stakeholders' perspective. Personal interviews were conducted with Spanish fishermen and surveys were sent to scientists and non-governmental organizations (NGOs). Local Ecological Knowledge was considered to be useful as fishermen possess unique expertise based on their continued interaction with the species and environment. Interviews allowed understanding the fishermen's perception on variations of stock abundance, distribution patterns, size of capture and seasonal fluctuations for both species. SWOT (Strength, Weaknesses, Opportunities and Threats)-analysis was used to study the different management measures. Main management strategies proposed by all stakeholders to reduce the bycatch of both species were spatial-temporal closure, minimum size and quotas. The Sole Bank was suggested as a temporarily closed area to protect blue shark juveniles during the summer months. The participation of stakeholders enriched the knowledge available and provided a broader data set now available for decision makers in the corresponding regional fisheries management organization (RFMOs).

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 & 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.

Domingo, A., Pons, M., Jimenez, S., Miller, P., Barcelo, C., & Swimmer, Y. (2012). Circle Hook Performance in the Uruguayan Pelagic Longline Fishery. *Bulletin of Marine Science, 88*(3), 499-511 https://doi.org/10.5343/bms.2011.1069

Circle hooks have been promoted as an alternative to traditional J-hooks in pelagic longline fisheries to minimize bycatch mortality and injury to sea turtles and other marine wildlife. We evaluated the effect of hook type (circle hook vs J-hook) on the catch and length composition of target and non-target species in the Uruguayan pelagic longline fishery, for both American- and Spanish-style longlines. The sample unit used for comparing catches was two consecutive sections of the longline, each with a different hook type. For the American-style longline 39,822 hooks were deployed in 108 paired sections, and for the Spanish-style 45,142 hooks were deployed in 238 paired sections. The catch of albacore tuna, Thunnus alalunga (Bonnaterre, 1788), was higher with circle hooks with both gears. The catch of shortfin mako shark, *Isurus oxyrinchus* (Rafinesque, 1810), also increased with the use of circle hooks, but only with the American-style longline. A decrease was observed in the catch of pelagic stingray, Pteroplatytrygon violacea (Bonaparte, 1832), with both gears, though it was significant only with the Spanish-style longline. The performance of circle hooks for other target species, such as swordfish, *Xiphias gladius* (Linnaeus, 1758), and sharks, and for bycatch species including sea turtles and seabirds remains unclear and requires further research.

dos Santos, M. N., Garcia, A., & Pereira, J. G. (2002). A Historical Review of the by-Catch from the Portuguese Surface Long-Line Swordfish Fishery: Observations on Blue Shark (*Prionace glauca*) and Short-Fin Mako (*Isurus oxyrinchus*). *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 54*(4), 1333-1340 Retrieved from https://iccat.int/en/pubs_CVSP.html

This paper review historical data on the by-catch from the Portuguese long-line swordfish fishery, namely on the blue shark (*Prionace glauca*) and the short-fin mako (*Isurus oxyrinchus*). This was done by analysing logbooks both for the North (ICCAT area 94B) and South Atlantic (ICCAT areas 96 and 97) areas, in order to detect any relationship on the ratio between the catches of swordfish and non-target species. Based on these analyses the Portuguese catches of sharks associated to the swordfish fishery were estimated. The seasonal nature of the catch rate was investigated. Catch rates for blue shark and swordfish, in the North Atlantic area, exhibit a pronounced seasonal and asynchronic nature. The highest catch levels of the blue shark are obtained during the 1st semester, while those of swordfish occur in September/October. No clear trend for the short-fin mako catch rate was observed, but they are slightly higher during the second semester.

Dulvy, N. K., Baum, J. K., Clarke, S., Compagno, L. J. V., Cortes, E., Domingo, A., . . . Valenti, S. (2008). You Can Swim but You Can't Hide: The Global Status and Conservation of Oceanic Pelagic Sharks and Rays. *Aquatic Conservation-Marine and Freshwater Ecosystems, 18*(5), 459-482 https://doi.org/10.1002/aqc.975

1. Fishing spans all oceans and the impact on ocean predators such as sharks and rays is largely unknown. A lack of data and complicated jurisdictional issues present particular challenges for assessing and conserving high seas biodiversity. It is clear, however, that pelagic sharks and rays of the open

ocean are subject to high and often unrestricted levels of mortality from bycatch and targeted fisheries for their meat and valuable fins.
2. These species exhibit a wide range of life-history characteristics, but many have relatively low productivity and consequently relatively high intrinsic vulnerability to over-exploitation. The IUCN-World Conservation Union Red List criteria were used to assess the global status of 21 oceanic pelagic shark and ray species.
3. Three-quarters (16) of these species are classified as Threatened or Near Threatened. Eleven species are globally threatened with higher risk of extinction: the giant devilray is Endangered, ten sharks are Vulnerable and a further five species are Near Threatened. Threat status depends on the interaction between the demographic resilience of the species and intensity of fisheries exploitation.
4. Most threatened species, like the shortfin mako shark, have low population increase rates and suffer high fishing mortality throughout their range. Species with a lower risk of extinction have either fast, resilient life histories (e.g. pelagic stingray) or are species with slow, less resilient life histories but subject to fisheries management (e.g. salmon shark).
5. Recommendations, including implementing and enforcing firming bans and catch limits, are made to guide effective conservation and management of these sharks and rays. Copyright (c) 2008 John Wiley & Sons, Ltd.

Fields, A. T., Fischer, G. A., Shea, S. K. H., Zhang, H., Abercrombie, D. L., Feldheim, K. A., . . . Chapman, D. D. (2018). Species Composition of the International Shark Fin Trade Assessed through a Retail-Market Survey in Hong Kong. *Conservation Biology, 32*(2), 376-389 https://doi.org/10.1111/cobi.13043

The shark fin trade is a major driver of shark exploitation in fisheries all over the world, most of which are not managed on a species-specific basis. Species-specific trade information highlights taxa of particular concern and can be used to assess the efficacy of management measures and anticipate emerging threats. The species composition of the Hong Kong Special Administrative Region of China, one of the world's largest fin trading hubs, was partially assessed in 1999-2001. We randomly selected and genetically identified fin trimmings (n = 4800), produced during fin processing, from the retail market of Hong Kong in 2014-2015 to assess contemporary species composition of the fin trade. We used nonparametric species estimators to determine that at least 76 species of sharks, batoids, and chimaeras supplied the fin trade and a Bayesian model to determine their relative proportion in the market. The diversity of traded species suggests species substitution could mask depletion of vulnerable species; one-third of identified species are threatened with extinction. The Bayesian model suggested that 8 species each comprised >1% of the fin trimmings (34.1-64.2% for blue [*Prionace glauca*], 0.2-1.2% for bull [Carcharhinus leucas] and shortfin mako [*Isurus oxyrinchus*]); thus, trade was skewed to a few globally distributed species. Several other coastal sharks, batoids, and chimaeras are in the trade but poorly managed. Fewer than 10 of the species we modeled have sustainably managed fisheries anywhere in their range, and the most common species in trade, the blue shark, was not among them. Our study and approach serve as a baseline to track changes in composition of species in the fin trade over time to better understand patterns of exploitation and assess the effects of emerging management actions for these animals.

Foster, D. G., Epperly, S. P., Shah, A. K., & Watson, J. W. (2012). Evaluation of Hook and Bait Type on the Catch Rates in the Western North Atlantic Ocean Pelagic Longline Fishery. *Bulletin of Marine Science, 88*(3), 529-545 https://doi.org/10.5343/bms.2011.1081

Research was conducted in 2002 and 2003 by NOAA's National Marine Fisheries Service, Southeast Fisheries Science Center, to investigate changes in hook design and bait type to reduce the bycatch of sea turtles on pelagic longlines in the western North Atlantic Ocean. The effectiveness of 18/0-20/0 circle hooks and 10/0 Japanese tuna hooks with squid (Illex spp.) and mackerel bait (Scomber scombrus Linnaeus, 1758) was evaluated against the industry standard 9/0 J-hooks with squid bait with respect to reducing sea turtle and shark interactions while maintaining swordfish (*Xiphias gladius* Linnaeus, 1758) and tuna (Thunnus spp.) catch rates. In total, 973,734 hooks were deployed during the study. Individually, circle hooks and mackerel bait significantly reduced both loggerhead [*Caretta caretta* (Linnaeus, 1758)] and leatherback [Dermochelys coriacea (Vandelli, 1761)] sea turtle bycatch. The combination of 18/0 circle hooks with mackerel bait was even more effective for loggerhead sea turtles and had a significant increase in swordfish catch by weight. The combination 18/0 circle hooks with squid bait resulted in a significant decrease in the swordfish catch and a significant increase in the catch rate of blue shark [*Prionace glauca* (Linnaeus, 1758)], bluefin tuna [Thunnus thynnus (Linnaeus, 1758)1, and albacore tuna [Thunnus alalunga (Bonnaterre, 1788)]. With all hook types, mackerel bait resulted in a significant decrease in blue shark, bigeye tuna [*Thunnus obesus* (Lowe, 1839)], and albacore tuna, but significantly increased the catch of porbeagle [*Lamna nasus* (Bonnaterre, 1788)] and shortfin mako (*Isurus oxyrinchus* Rafinesque, 1810).

Fowler, G., & Campana, S. (2009). Commercial by-Catch Rates of Shortfin Mako (*Isurus oxyrinchus*) from Longline Fisheries in the Canadian Atlantic. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 64*(5), 1668-1676 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/SCRS/SCRS-08-148_Fowler_and_Campana.pdf

Shortfin makos (*Isurus oxyrinchus*) are a high-value by-catch of pelagic longline fisheries off the eastern coast of Canada. Annual catches in Canadian waters average 60-80 mt per year. Therefore, Canadian catches represent but a small part of that for the North Atlantic population as a whole. A standardized catch rate series was developed based on observed foreign tuna fleets fishing within Canadian waters and the Canadian swordfish fleet. There was no consistent trend in abundance since 1996 based on the standardized catch rate analysis.

French, R. P., Lyle, J. M., Lennox, R. J., Cooke, S. J., & Semmens, J. M. (2019). Motivation and Harvesting Behaviour of Fishers in a Specialized Fishery Targeting a Top Predator Species at Risk. *People and Nature, 1*(1), 44-58 https://doi.org/10.1002/pan3.9

1. Effective management of wildlife resources depends on understanding and cooperating with the human users of the resource, particularly as policies may be rejected if user satisfactions are not met. In Australia, recreational anglers can legally target a migratory top predator, the shortfin mako shark *Isurus oxyrinchus*, which is also a species at risk. It is assumed that most of the sharks are released and population remains minimally impacted; yet, the actual release rate of this species is unknown and little information is available about anglers that participate in this fishery.
2. Fishing motivations and behaviours were ascertained by a web survey of recreational shark anglers from three south-eastern Australian states. Respondents reported that ~70% of the captured makos were released, with significant geographic variation in release rates between states.

3. Most anglers reported being motivated by the catch-based objectives, the thrills and challenges, rather than harvest-based motivations. However, there were significant differences in harvesting motivation among states. This could be attributed to the varying value assigned to shortfin mako as a sport fish and table fish among regions. Additionally, higher rates of release among anglers from New South Wales may be linked to increased opportunity for resource substitution (i.e. greater diversity of game fish species) and established norms driven by current catch-and-release fisheries in that region.
4. Increased participation in catch-and-release fishing may be achieved by establishing behavioural norms by the provision of more desirable incentives to release sharks during fishing competitions. Data on regional variation in release rates yield important information for managers to target specialized fishers to incentivize catch-and-release fishing with an objective of changing behaviour.
5. Many anglers understand that sharks are important to marine ecosystems and messaging may be important to deliver effective management given that most anglers are motivated by catch-based objectives even though many enjoy harvesting makos. Information on natural resource user motivations and satisfactions, such as studied here, has the potential to guide management actions and the ways in which managers interact with resource users.

French, R. P., Lyle, J. M., Twardek, W. M., Cooke, S. J., & Semmens, J. M. (2019). A Characterization of Australian Shortfin Mako Shark Anglers. *Marine Policy, 110* https://doi.org/10.1016/j.marpol.2019.103550

Understanding the human dimensions of recreational fisheries is critical to the development of effective fisheries management regulations. This study aimed to characterize Australian shortfin mako shark (*Isurus oxyrinchus*) anglers in terms of their gear use, perceptions on circle hooks, perceptions on sharks and shark conservation, and attitudes towards fisheries management. A targeted web survey was completed by 272 shortfin mako anglers distributed across southeastern Australia. Responses were compared across angler subgroups in relation to their state of residence, membership to an angling club, and tendency to release or keep captured sharks. Overall, anglers' perceptions about how their fishing behaviours and gear choices may affect the survival of released shortfin mako sharks were quite in line with existing scientific knowledge though anglers believed their behaviours have less of an impact on shark stocks than other threats such as commercial fisheries. Gear selection was determined largely by fishing preference (harvest or catch-and-release) of the angler, with those practicing catch-and-release more frequently using circle hooks. State of residence also influenced the perceptions of anglers towards sharks and shark survival as well as their attitudes towards fisheries management. Angler support for precautionary management suggests that a better understanding of the potential impacts of recreational fishing on shark stocks may assist in promoting greater accountability and responsible fishing practices amongst these resource users; however, improved communication between recreational fishers, management authorities, and fisheries scientists is a necessary precursor to this step.

Garcia-Cortes, B., Ortiz de Urbina, J. M., Ramos-Cartelle, A., & Mejuto, J. (2008). Trials Using Different Hook and Bait Types in the Configuration of the Surface Longline Gear Used by the Spanish Swordfish (*Xiphias gladius*) Fishery in the Atlantic Ocean. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 62*(6), 1793-1830 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/SCRS/SCRS-08-176_Garcia-Cortes_et_al.pdf

Three types of hooks and baits were tested on two swordfish longliners over a period of 480 days at sea in five zones of the North and South Atlantic Ocean. Nominal CPUE data would suggest that the overall catch rates in weight of the fish species in general were reduced with the alternate hooks and baits tested. Overall rates (+7% and -8%) and (+3% and -11%) were found for the swordfish and blue shark, respectively in relation to the hook and bait combination of reference. The shortfin mako exhibited substantial decreases (-9% and -61%). For the billfish group, however, the all rates underwent an increase (+7% and +49%). For the sea turtle species CAT (*Caretta caretta*) and LOL (Lepidochelys olivacea), the nominal catch rates using alternate hooks and baits tested were generally found to increase (+2%, +557%) and (+203%, -66%), respectively. Standardized log normal CPUEs showed that "zone" was the most important significant factor explaining the variability in the CPUE of all the species. "Hook type" was only significant in the billfish group, while "bait type" proved to be significant for the shortfin mako, several other fish and the sea turtle C. caretta. A comparison of the standardized CPUEs would suggest that changing the hook and maintaining the same type of bait could result in an increase in the level of sea turtles by-catch that become hooked in external or internal locations. The use of squid as bait instead of mackerel would cause a considerable increase in the number of some species of sea turtles being hooked either externally or internally, regardless of the type of hook used. No seabird interaction occurred during the whole experiment.

González-Ania, L. V., Fernández-Méndez, J. I., Castillo-Géniz, J. L., Ramírez-Soberón, G., & Haro-Ávalos, H. (2021). *Update on Standardized Catch Rates for Mako Shark (Isurus oxyrinchus) in the 2006-2019 Mexican Pacific Longline Fishery Based Upon a Shark Scientific Observer Program*. Paper presented at the ISC/21/SHARKWG-1. Webinar Retrieved from http://isc.fra.go.jp/reports/shark/shark_2021_1.html

Abundance indices for mako shark (*Isurus oxyrinchus*) in the northwest Mexican Pacific for the period 2006-2019 were estimated using data obtained through a pelagic longline observer program, updating similar analyses made in 2014 and 2017. Individual longline set catch per unit effort data, collected by scientific observers, were analyzed to assess effects of environmental factors such as sea surface temperature, distance from mainland coast and time-area factors. Standardized catch rates were estimated by applying two generalized linear models (GLMs). The first model (using a quasi-binomial likelihood and a complementary log-log link function) estimates the probability of a positive observation and the second one estimates the mean response for non-zero observations, using a lognormal error distribution. The importance of factors included in the models is discussed. The results of this analysis point at the abundance index trends being close to stability in the analyzed period.

Gonzalez-Armas, R., Ho, J. S., & Hernandez-Trujillo, S. (2012). A New Regional Record for the Pandarid Copepod, Dinemoura Producta (Muller, 1785), Parasitic on the Shortfin Mako Shark Captured Off Cabo San Lucas, Mexico. *Crustaceana, 85*(8), 1019-1023 https://doi.org/10.1163/156854012x650205

No abstract.

Howard, S. (2015). *Mitigation Options for Shark Bycatch in Longline Fisheries*. Ministry for Primary Industries Retrieved from http://www.mpi.govt.nz/news-resources/publications.aspx

A systematic review of literature addressing methods of reducing shark catch rates on longline fishing gear was conducted using academic publication databases and the Ministry for Primary Industries' publications database. Gear technology as well as operational and environmental variables were evaluated as potential elasmobranch bycatch reduction methods for use in New Zealand commercial longline fisheries.

Twenty candidate shark bycatch reduction methods were identified. The criteria used to assess these methods were weighted toward approaches currently ready for deployment in commercial fisheries. The methods of mitigating shark bycatch that ranked highest in this assessment are already used extensively in New Zealand longline fisheries. These are nylon leaders, large hooks and squid bait. Nylon leaders enable sharks to escape by biting off from fishing gear after capture. The 16/0 hooks commonly used in New Zealand surface longline fisheries have been associated with reduced blue shark (*Prionace glauca*) and pelagic stingray (Pteroplatytrygon violacea) catch rates, compared to 14/0 circle hooks and J-hooks respectively. Circle hooks are more often associated with increased shark catch rates, which may be due to increased retention on the line rather than increased total catches. Circle hooks complement the use of nylon leaders by reducing the incidence of gut hooking, which improves the odds of survival for animals that bite off the leader. 17/0 and 18/0 circle hooks are common in surface longline fisheries internationally and it is possible that a shift to these larger hooks could further reduce elasmobranch bycatch by making gear less available to smaller individuals.

Other shark bycatch reduction methods that scored highly in this assessment include a shift in setting depth, the use of weak hooks, eliminating lightsticks, and developing artificial bait. A shift in setting depth holds more promise in bottom longline fisheries than in surface longline fisheries, but the research that lead to this conclusion was conducted outside of New Zealand and addressed species not found in New Zealand waters. Understanding the effect of altering setting depth on local elasmobranch species, target catches and vessel operations would require further investigation.

Weak hooks scored highly because they could be very straightforward to implement, but little peer reviewed information was available regarding their impact on shark catch rates, post release survival, or target catch rates, particularly those of large tuna. Likewise, eliminating lightsticks scored highly largely due to ease of implementation. Despite the significant relationships between shark catches and lightstick use reported in the literature, it is probable that the practical significance of such a measure is not great.

Unlike weak hooks or eliminating lightsticks, artificial baits manufactured from fish processing waste scored highly in this assessment because they have the potential to strongly reduce shark catch rates. However, this approach would require extensive development, including creating new formulae from locally available waste products, conducting field trials, and establishing manufacturing capability.

By condensing and summarising available data on how shark and target species' catch rates are influenced by different operational and environmental parameters, this review makes a large amount of information about shark bycatch mitigation options accessible. The scoring system used to assess those options illustrates how the conclusions presented here were reached. This evidence together with a transparent assessment framework is intended to encourage discussion about future directions for shark bycatch mitigation in New Zealand's longline fisheries.

Hurley, P. C. F. (1998). A Review of the Fishery for Pelagic Sharks in Atlantic Canada. *Fisheries Research, 39*(2), 107-113 https://doi.org/10.1016/S0165-7836(98)00177-5

A domestic fishery for pelagic sharks has been developing in Atlantic Canada since 1990. Landings consist primarily of three species, porbeagle (*Lamna nasus*), shortfin mako (*Isurus oxyrinchus*), and blue (*Prionace glauca*) sharks. A small but increasing quantity is landed as unspecified sharks. Porbeagle sharks are caught primarily in a directed longline fishery while shortfin makos are caught primarily as by-catch in the swordfish longline fishery. Small quantities of all three species are landed as by-catch in other fisheries. Although blue shacks are a significant by-catch in the swordfish and tuna longline fisheries, landings come primarily from a developing directed longline fishery. This developing fishery has been limited by market. Landings in 1994 totalled 1545 t of porbeagle, 157 t of shortfin mako, 113 t of blue, and 107 t of unspecified sharks. Fisheries regulations were amended in 1994 to permit the management of this fishery. A management plan, announced in July 1994, established precautionary catch levels, st limited number of exploratory licenses, gear restrictions, a prohibition on 'finning' and submission of logbooks. Extreme caution has been advised in the development of this fishery due to elasmobranch life history traits, the history of elasmobranch fisheries, and the lack of information necessary for stock assessments.

Jacobsen, I. P., Scott-Holland, T., & Bennett, M. B. (2013). Lepadidae Barnacles (Lepadiformes: Lepadomorpha) in Association with Copepods Parasitising Pelagic Elasmobranchs in the Western Pacific. *New Zealand Journal of Marine and Freshwater Research, 47*(1), 120-123 https://doi.org/10.1080/00288330.2012.732953

The following provides a detailed account of associations between stalked barnacles and copepods collected from elasmobranchs in the West Pacific Ocean. Ectoparasitic copepods were collected from blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*) caught as bycatch in the Eastern Tuna and Billfish longline fishery. Up to eight barnacles from the family Lepadidae were observed on three species of copepods; Pandarus satyrus, Dinemoura latifolia, and Ecthrogaleus coleoptratus. The majority were attached to the fourth dorsal plate with barnacle total length at times exceeding 60% of the copepod host length. Only the fourth study to document this type of association, it also identifies E. coleoptratus as a new host record for the family Lepadidae.

Julian, F., & Beeson, M. (1998). Estimates of Marine Mammal, Turtle, and Seabird Mortality for Two California Gillnet Fisheries: 1990-1995. *Fishery Bulletin, 96*(2), 271-284 Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fish-bull/julian.pdf

Incidental kills of marine mammals, turtles, and seabirds are estimated for the California drift gillnet fishery for broadbill swordfish, *Xiphias gladius*, common thresher shark, *Alopias vulpinus*, and shortfin mako shark, *Isurus oxyrinchus*, and the set gillnet fishery for California halibut, Paralichthys californicus, and Pacific angel shark, Squatina californica, for the period July 1990 through December 1995. Estimates were based on observations made by National Marine Fisheries Service observers placed aboard commercial fishing vessels. Yearly observer coverage varied between 4% and 18% of estimated total effort. Total fishing effort-days per California Department of Fish and Game fishing block was used as the measure of effort for the drift and set gillnet fisheries. Incidental kill was estimated from observed

data and estimates of total effort by using mean-per-unit and ratio estimators. Additional bycatch data collected by NMFS observers were used to derive kill estimates of marine turtles and seabirds.
In the drift gillnet fishery, seven out of 387 mammals observed entangled were released alive. In the set gillnet fishery, five out of 1,263 mammals observed entangled were released alive. Estimates of incidental kill are presented along with estimates of entanglement for species that were observed to be released alive. For the period under consideration, the estimated mortality for the drift gillnet fishery was over 450 marine mammals each year. A total of 20 turtles and 3 seabirds were observed entangled during the entire period. The most frequently en tangled species in this fishery were common dolphins, Delphinus spp., and northern elephant seals, Mirounga angustirostris. Estimated cetacean mortality in the driftnet fishery decreased from 650 in 1991 to 417 in 1995; pinniped mortality decreased from 173 in 1991 to 116 in 1995. Estimated cetacean mortality in the set gillnet fishery ranged from a high of 38 in 1991 to a low 14 in 1993; pinniped mortality rose to a high of 4,777 in 1992 and then decreased to 1,016 in 1995. We postulate that there has been a decline in the number of pinnipeds and cetaceans in the setnet fishery owing to area closure. No similar proposal can be made for the driftnet fishery. The most frequently entangled mammals in the setnet fishery were California sea lions, Zalophus californianus, and harbor seals, Phoca vitulina. Six turtles and 1,018 seabirds were estimated entangled in this fishery during the NMFS Observer Program from July 1990 to December 1995.

Kai, M. (2019). Spatio-Temporal Changes in Catch Rates of Pelagic Sharks Caught by Japanese Research and Training Vessels in the Western and Central North Pacific. *Fisheries Research, 216*, 177-195 https://doi.org/10.1016/j.fishres.2019.02.015

Blue shark and shortfin mako are key pelagic shark species distributed throughout the temperate and tropical waters of the world's oceans. These species are caught in the North Pacific by Japanese longline fisheries as bycatch and occasionally targeting blue shark. Japanese research and training vessels (JRTVs) have been collecting fishery-independent data on these sharks in the western and central North Pacific since 1992. However, the catch per unit of effort (CPUE) estimated from the fishery-independent data had not been used for stock assessments due to an issue concerning reporting after the 2000s. In this study, a statistical filtering method was used to remove unreliable set-by-set data collected by JRTVs. The nominal CPUE of the JRTVs was then standardized using the spatio-temporal generalized linear mixed model to provide the spatial and temporal changes in the CPUEs of these sharks in the North Pacific. The hotspots of blue shark appeared in temperate waters of the western and central North Pacific, whereas those of shortfin mako were distributed in coastal and offshore waters along the Kuroshio-Oyashio transition zone and the Mixed Water Region. The yearly changes in the CPUE of blue shark illustrated a downward trend until 2008 and an upward trend thereafter, whereas those of shortfin mako exhibited a flat trend with large fluctuations from 1994 to 2008, and a down-and-up trend thereafter. The information predicted from the fishery-independent data is very useful for improving the stock assessment and management of these sharks as it provides an understanding of spatio-temporal changes in the hotspots and temporal changes in the catch rates.

Keller, B., Swimmer, Y., & Brown, C. (2020). *Review on the Effect of Hook Type on the Catchability, Hooking Location, and Post-Capture Mortality of the Shortfin Mako, Isurus oxyrinchus*. https://doi.org/10.25923/gx1p-m838

Due to the assessed vulnerability for the North Atlantic shortfin mako, *Isurus oxyrinchus*, ICCAT has identified the need to better understand the use of circle hooks as a potential mitigation measure in

longline fisheries. We conducted a literature review related to the effect of hook type on the catchability, anatomical hooking location, and post-capture mortality of this species. We found twenty eight papers related to these topics, yet many were limited in interpretation due to small sample sizes and lack of statistical analysis. In regards to catchability, our results were inconclusive, suggesting no clear trend in catch rates by hook type. The use of circle hooks was shown to either decrease or have no effect on at-haulback mortality. Three papers documented post-release mortality, ranging from 23-31%. The use of circle hooks significantly increased the likelihood of mouth hooking, which is associated with lower rates of post-release mortality. Overall, our review suggests minimal differences in catchability of shortfin mako between hook types, but suggests that use of circle hooks likely results in higher post-release survival that may assist population recovery efforts.

Kimoto, A., & Yokawa, K. (2012). Standardization Cpue of Shortfin Mako Sharks Caught by Japanese Longliners in the Atlantic in the Period between 1994 and 2009. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 68*(5), 1908-1914 Retrieved from http://www.iccat.int/Documents/CVSP/CV068_2012/no_5/CV0680501908.pdf

The Japanese logbook system for distant-water longliners started collecting shortfin mako data in 1994. Because part of the Japanese longliners released/discarded their shortfin mako catch and the Japanese logbook system does not require reporting these in the regular base, the catch and effort data on shortfin mako, which were supposed to report all the longline catches, were used to analyze the CPUE. The estimated annual trend suggested that at least no notable changes were occurred in the exploitable abundances of shortfin mako in the both North and South Atlantic.

Levesque, J. C. (2007). *A Comprehensive Review of the Biology and Preliminary Investigation of Interactions with the Us Pelagic Longline Fishery for the Shortfin (Isurus oxyrinchus) and Longfin (Isurus paucus) Mako Sharks.* (M.S. Marine Biology), Nova Southeastern University, Retrieved from https://nsuworks.nova.edu/cnso_stucap/175

The shark genus Isurus is cosmopolitan and represented by two species: the shortfin mako *Isurus oxyrinchus* and the longfin mako Isurus paucus. Besides a few cetaceans (Visser et al., 2000) and man, the adult mako shark is not prey to any marine animal, but is considered an apex predator at the top of the marine environment food web. Shortfin and longfin mako sharks are often captured incidentally in various pelagic fisheries throughout the world and may be vulnerable to overfishing (Baum et al., 2003; ICCA T, 2004). Researchers have documented such declines and many shark populations in general at various geographical locations are believed to be at critical population levels or may have already collapsed (Baum et al., 2003; Baum and Myers, 2004; Baum and Myers, 2005) due to direct or indirect fishing activities (Martin, 2005). Sharks are long lived, slow growing, reach sexual maturity late in their life history, and produce few offspring; thus, overall population growth is slower and sharks have a lower growth rate than most teleosts (Musick, 1999). According to the JUCN World Conservation Union's Red List of Threatened and Endangered Species, the shortfin mako shark was assessed and listed under the category Lower Risk (Near Threatened (NT)) in 2002. Taxa under this category do not qualify for Conservation Dependent status, but are close to qualifying under the Vulnerable category. In 2005, the longfin make shark was assessed and listed in the Vulnerable category under the same Red List of Threatened and Endangered Species. More recently, the Committee on the Status of the Endangered Wildlife in Canada (COSEWIC) drafted an assessment and population status for the shortfin mako shark (COSEWIC, 2006). Based on the review, the committee decided to list the species as Threatened under

the criteria A2b. According to the COSEWIC definitions, Threatened is defined as a species likely to become endangered if limiting factors are not reversed. Presently, little to no information is available for the longfin mako shark and limited information is available for the shortfin mako shark. Although COSEWIC (2006), ICCA T (2004), and IUCN (2002) have conducted status reviews on the shortfin mako shark, this report provides the first and only complete comprehensive review that has used all available information on the shortfin and longfin mako shark.

This comprehensive review was primarily based on published literature obtained by using the Nova Southeastern University library online database search system and the National Marine Fisheries Service (NMFS) Pelagic Observer Program (POP) database.

The shortfin mako shark is an apex predator that has some special evolutionary traits unlike any other shark species. There are only five species classified in the Lamnidae family (shortfin mako, longfin mako, porbeagle, salmon, and white shark). Review of molecular genetics studies revealed that only one species of the shortfin mako shark exist worldwide (Heist et al., 1996). Distinct from most sharks, the shortfin mako shark has the ability to regulate its internal body temperature and closely resembles the physiology of some tunas. Distribution information has revealed the shortfin and longfin mako shark are highly migratory species found in every major ocean. Both species are captured in commercial fisheries (pelagic longlines and gillnets) worldwide and abundance trends show that the shortfin mako shark has declined over the last 30 years. The shortfin mako shark is captured in great numbers and ranks as one of the most dominant species caught in pelagic longlines and gillnets. The longfin mako, although also caught in similar fishing gears, is rare in catch composition data. Today, worldwide size composition data shows that male shortfin mako sharks are being caught at or below the size at maturity and below the female shortfin mako shark size at maturity. Moreover, size composition information shows that commercial fisheries are exploiting virtually the species entire size range (60-340 em FL). Recent age and growth information studies indicate that the shortfin mako shark is one of the slowest growing and longest lived extant shark species. Reproduction information suggests that the shortfin mako shark has one of the longest gestation periods and reproductive cycles within the elasmobranchs, More importantly, intrauterine cannibalism has recently been documented in the shortfin mako shark, which has only been previously reported in the sand tiger shark Carcharius taurus. Unlike most shark species, the shortfin mako shark is economically important for both its quality of meat and fins. Even though the species is physiologically unique, economically important, and exploited in significant relatively large numbers, this review has revealed that there are limited specific regulations and management plans currently in place, and recovery plans for the shortfin mako shark are lacking.

Based on the results of this review, it is highly recommended that further research in age specific population dynamics, fishery yield models, and specific domestic and international management measures be implemented for the conservation and sustainability of the longfin and shortfin mako sharks.

Levine, M., Collier, R. S., Ritter, E., Fouda, M., & Canabal, V. (2014). Shark Cognition and a Human Mediated Driver of a Spate of Shark Attacks. *Open Journal of Animal Sciences, 04*(05), 263-269 https://doi.org/10.4236/ojas.2014.45033

Five unprovoked shark attacks are reported from Sharm-El-Sheikh, Egypt, between 30 November and 5 December 2010. Three of the five attacks are attributed to an oceanic whitetip shark, Carcharinus longimanus with a distinctive crescent-shaped notch in the upper lobe of the caudal fin. The shark was

observed during the first attack on a snorkeler and photographed underwater during the second shark attack on a swimmer. In a video taken several months prior to the attacks, the same shark is hand-fed underwater by a divemaster with additional fish in a pack over his buttock. The shark can be seen swimming behind the divemaster while he removed additional fish from this pack. In Victims 1, 2 and 5, the shark removed an extensive amount of tissue from the victims' buttock. The three victims also lost a hand and/or a portion of their forearm, suggesting the injuries were inflicted by a shark conditioned to associating food with hand-feedings and the human form. The remaining two attacks, Cases 3 and 4, were attributable to the shortfin mako shark, *Isurus oxyrinchus*. This was determined from a unique dental pattern of the right side of the upper jaw due to a prior injury. This same "misalignment" dental pattern was observed in the injuries sustained by Victims 3 and 4. We conclude that the shortfin mako shark was responsible for the attacks on Victims 3 and 4, and the oceanic whitetip shark was the causal species of attacks on Victims 1, 2, and 5.

Liu, X., Wu, Y., Zhang, X., Shen, L., Brazeau, A. L., Adams, D. H., . . . Chen, D. (2019). Novel Dechlorane Analogues and Possible Sources in Peregrine Falcon Eggs and Shark Livers from the Western North Atlantic Regions. *Environmental Science & Technology, 53*(7), 3419-3428 https://doi.org/10.1021/acs.est.8b06214

During the investigation of dechlorane-related chemicals in North American wildlife, two unknown polychlorinated compounds (referred to as U1 and U2) were discovered. After extensive sample cleanup, structural information on U1 and U2 was characterized by gas chromatography (GC) coupled with single quadrupole mass spectrometer (MS) or GC-quadrupole time-of-flight (QToF) MS. Mass spectral evidence suggests that both U1 and U2 are structurally related to Dechlorane 603 (Dec603; C17H8Cl12), an analogue of the chlorinated flame retardant Dechlorane Plus. From the results we suspect U1 (C17H9Cl11) to be a monohydro analogue of Dec603 (i.e., one chlorine atom in Dec603 is replaced by a hydrogen atom). U1 may be formed via the degradation of Dec603's stereoisomers or present as an impurity in commercial Dec603 products. Mass spectral characterization of U2 (C17H7OCl11) suggests it is a carbonylic derivative of Dec603, likely formed via metabolic transformation of Dec603 or its photoisomer. Semiquantitative measurement revealed that U1 and U2 were present at estimated median concentrations of 49 ng/g lipid weight (lw) and 59 ng/g lw in peregrine falcon (Falco peregrinus) eggs, from the mid-Atlantic region of the United States, and 4.6 and 3.0 ng/g lw in shortfin mako shark (*Isurus oxyrinchus*) livers from the western North Atlantic Ocean, respectively. Our results demonstrate the occurrence of these two novel Dec603-related chemicals in both terrestrial and aquatic ecosystems.

Lowry, M., Williams, D., & Metti, Y. (2007). Lunar Landings—Relationship between Lunar Phase and Catch Rates for an Australian Gamefish-Tournament Fishery. *Fisheries Research, 88*(1-3), 15-23 https://doi.org/10.1016/j.fishres.2007.07.011

Catch-per-unit-of-effort (CPUE) data were collected from anglers participating in gamefish tournaments off the coast of New South Wales, Australia, over nine consecutive years (1994–2003). Mean catch rates for 381 tournament days were aggregated by "lunar phase day" in order to analyse relationships between CPUE and lunar phase for eight primary gamefish species. Circular–linear correlation analysis identified significant relationships between moon phase and CPUE for black marlin (Makaira indica), blue shark (*Prionace glauca*), shortfin mako shark (*Isurus oxyrinchus*), dolphin fish (Coryphaena hippurus), and yellowfin tuna (Thunnus albacares) while no significant relationship was evident for blue

marlin (Makaira mazara), striped marlin (Tetrapterus audax) and tiger shark (Galeocerdo cuvier). Periodic regression was used to identify the nature of the relationship between lunar phases and catch rates for these species. A consistent pattern of catch rates peaking over the period from the new moon to the first quarter was observed for blue shark, mako shark, dolphin fish and yellowfin tuna. Results for black marlin differed, with catch rates increasing to a peak between the full moon and the last quarter. We suggest that the observed variability in CPUE maybe a result of the movement of prey species in association with lunar phase. Further, we hypothesise that the observed species-specific differences in CPUE of gamefish are primarily mediated by physiological adaptations and limitations, which directly affect the ability of these predators to maintain access to their prey.

Madrid, S. (2009). *Report of the 2008 Shark Stock Assessment Session (Madrid, Spain - September 1 to 5, 2008).* ICCAT 5. Retrieved from https://www.iccat.int/Documents/Meetings/Docs/2008_SHK_Report.pdf

The Meeting was held in Madrid, Spain from September 1 to 5, 2008. This meeting responds to the request from the Commission contained in the Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Three Fisheries Managed by ICCAT [Rec. 04-10], for the SCRS to carry out stock assessments of the Atlantic shortfin mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*).

Marin, A., Serna, J., Robles, C., Ramirez, B., Reyes-Flores, L. E., Zelada-Mazmela, E., . . . Alfaro, R. (2018). A Glimpse into the Genetic Diversity of the Peruvian Seafood Sector: Unveiling Species Substitution, Mislabeling and Trade of Threatened Species. *PLOS ONE, 13*(11), e0206596 https://doi.org/10.1371/journal.pone.0206596

Peru is one of the world's leading fishing nations and its seafood industry relies on the trade of a vast variety of aquatic resources, playing a key role in the country's socio-economic development. DNA barcoding has become of paramount importance for systematics, conservation, and seafood traceability, complementing or even surpassing conventional identification methods when target organisms show similar morphology during the early life stages, have recently diverged, or have undergone processing. Aiming to increase our knowledge of the species diversity available across the Peruvian supply chain (from fish landing sites to markets and restaurants), we applied full and mini-barcoding approaches targeting three mitochondrial genes (COI, 16S, and 12S) and the control region to identify samples purchased at retailers from six departments along the north-central Peruvian coast. DNA barcodes from 131 samples were assigned to 55 species (plus five genus-level taxa) comprising 47 families, 24 orders, and six classes including Actinopterygii (45.03%), Chondrichthyes (36.64%), Bivalvia (6.87%), Cephalopoda (6.11%), Malacostraca (3.82%), and Gastropoda (1.53%). The identified samples included commercially important pelagic (anchovy, bonito, dolphinfish) and demersal (hake, smooth-hound, Peruvian rock seabass, croaker) fish species. Our results unveiled the marketing of protected and threatened species such as whale shark, Atlantic white marlin, smooth hammerhead (some specimens collected during closed season), shortfin mako, and pelagic thresher sharks. A total of 35 samples (26.72%) were mislabeled, including tilapia labeled as wild marine fish, dolphinfish and hake labeled as grouper, and different shark species sold as "smooth-hounds". The present study highlights the necessity of implementing traceability and monitoring programs along the entire seafood supply chain using molecular tools to enhance sustainability efforts and ensure consumer choice.

Matsunaga, H. (2009). Estimation of Catches for Blue Shark and Shortfin Mako by the Japanese Tuna Longline Fishery in the Atlantic Ocean, 1994-2006. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 64*(5), 1683-1689 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/SCRS/SCRS-08-150_Matsunaga_AUG%2028%2008.pdf

Catches for blue shark and shortfin mako caught by the Japanese tuna longline fishery in the Atlantic Ocean were estimated using the species specific logbook data from 1994 to 2006 filtered with a 80% reporting rate. Yearly catches of blue shark in the entire region were estimated to be 112,000-359,000 (mean 230,000 t) in number and 2,900-9,700 metric ton (mean 5,900 t) in weight. Catches of shortfin mako were estimated to be 3,400-13,900 (mean 6,70 t) and 120-640 tons (mean 27 t). Though decreasing trends were observed in both catch number and weight of the two species until 2002, after then recoveries were recognized.

Matsunaga, H. (2009). Standardized Cpue for Blue Shark and Shortfin Mako Caught by the Japanese Tuna Longline Fishery in the Atlantic Ocean. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 64*(5), 1677-1682 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/SCRS/SCRS-08-149_Matsunaga_AUG%2028%2008.pdf

The standardized CPUEs for blue shark and shortfin mako caught by the Japanese tuna longline fishery in the Atlantic Ocean were updated using filtered logbook data during 1971-2006 for blue shark and 1994-2006 for shortfin mako whose reporting rates were more than 80%. Blue shark CPUE shows some fluctuations and relatively stable trends during the past three decades for North, South and whole Atlantic stock hypotheses. Shortfin mako CPUE indicates decreasing trend until 2001 but after then recovery to the level at beginning is observed.

Matsunaga, H., & Takeuchi, Y. (2008). Estimation of Shortfin Mako Catches by Japanese Tuna Longline Vessels in the Atlantic Ocean by Two Methods. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 62*(6), 2070-2074 Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.495.9747&rep=rep1&type=pdf

Shortfin mako catches by the Japanese longline fishery in the Atlantic Ocean were estimated using the logbook data from 1971 to 1993 filtered with reporting rate by two methods. Difference between the two methods is remarkable after 1982 both North and South Atlantic. It is difficult to estimate the catch of shortfin mako because the two methods led to the different results. This problem also relates to the calculation of standardized shortfin mako CPUE.

Matsunaga, H., Nakano, H., Ishibashi, Y., & Nakayama, K. (2003). Estimation of the Amount of Shark Landing by Species in the Main Fishing Ports of Japan. *Nippon Suisan Gakkaishi, 69*(2), 178-184 https://doi.org/10.2331/suisan.69.178

To clarity the amount of shark landing by both species and fishing methods in Japan, an investigation on shark landing at the main fishing ports was conducted. The annual average weight of landing in the

product form for all shark species and blue shark by all fishing methods from 1992 to 1998 were estimated to be 19,600 and 11,600 tons respectively. Those by the longline were estimated to be 15,000 and 11,000 tons respectively. These weights became 28,700, 18,800, 23,400 and 17,800 tons after conversion to whole body weight. In all cases, the landing of the blue shark was dominant and occupied 61-79%. Excluding the blue shark, salmon shark, shortfin mako and thresher sharks were landed in relatively large amounts and occupied about 10, 10 and 5% respectively. A declining tendency in the amount of landing for those main species was not observed.

Megalofonou, P., Yannopoulos, C., Damalas, D., De Metrio, G., Deflorio, M., & de la Serna, J. M. (2005). Incidental Catch and Estimated Discards of Pelagic Sharks from the Swordfish and Tuna Fisheries in the Mediterranean Sea. *Fishery Bulletin, 103*(4), 620-634 Retrieved from http://fishbull.noaa.gov/1034/mega.pdf

Large pelagic sharks are caught incidentally in the swordfish and tuna fisheries of the Mediterranean Sea. In our study, twelve shark species were documented as bycatch over three years from 1998 to 2000. Blue shark (*Prionace glauca*) was the predominant species in all gears and areas examined. Shortfin mako (*Isurus oxyrinchus*), common thresher shark (*Alopias vulpinus*), and tope shark (*Galeorhinus galeus*) were the next most abundant shark species found in more than half of the areas sampled. Catch composition varied both in the areas and gears investigated. Sharks represented 34.3% in weight of total catches sampled in the Alboran Sea and 0.9% in the Straits of Sicily. Higher shark catches were observed in the swordfish longline fishery, where a nominal CPUE value reached 3.8 sharks/1000 hooks in the Alboran Sea. Size distribution by fishing gear varied significantly. Albacore longline catches consisted mainly of juveniles, whereas subadult and adult specimens were more frequent in the swordfish longline and drift-net fishery. The percentage of sharks brought onboard alive was exceptionally high; only 5.1% of the specimens died. Few discards (seven blue shark) were recorded in the Greek longline fleet during onboard sampling in the Aegean Sea.

Mejuto, J., Punzon, A., & Gonzalez, F. (2010). Report of Ec-Spain on the Atlantic *Lamna nasus*: Ices and Iccat Meeting 2009. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 65*(6), 2094-2097 Retrieved from https://www.iccat.int/Documents/Meetings/Docs/2009-SCRS_ENG.pdf

This paper summarize the most important Spanish fisheries within the ICCAT, ICES and NAFO convention areas where potential impact on porbeagle could be expected based on the areas of distribution of this species and their geographical overlap with the areas of activity of some of these fleets. Any targeted fishery is developed by Spain on this species. The Spanish surface longline targeting swordfish (*Xiphias gladius*) within the ICCAT convention area has sporadically caught porbeagle as a low prevalent by-catch in the North and South Atlantic areas, with the two most prevalent shark species being blue shark (*Prionace glauca*) and, to a lesser extent, shortfin mako (*Isurus oxyrinchus*). The paper summarize some of the old and recent scientific references on this Spanish fleet where information on porbeagle was reported since mid eighties of last century about, areas of activity, level of catches, catch rates, size, length-weight relationships, sex-ratio at size, relative prevalence, etc. as well as recent catch estimations and standardized CPUE trends. The porbeagle is a very rare by-catch within ICES and NAFO fisheries of CE-Spain and the level of their possible by-catch should be considered null or statistically negligible. The paper also summarizes several contributions presented to the working group of year 2009.

Mejuto, J., Garcia-Cortes, B., Ramos-Cartelle, A., & De la Serna, J. M. (2009). Standardized Catch Rates for the Blue Shark (*Prionace glauca*) and Shortfin Mako (*Isurus oxyrinchus*) Caught by the Spanish Longline Fleet in the Atlantic Ocean During the Period 1990-2007. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 64*(5), 1509-1521 Retrieved from http://www.iccat.int/Documents/CVSP/CV064_2009/no_5/CV0640501509.pdf

Standardized catch per unit of effort were obtained for the shortfin mako and blue shark using General Linear Modeling (GLM) procedures from trips carried out by the Spanish surface longline fleet targeting swordfish in the North and South Atlantic Ocean over the periods 1990-2007 and 1997-2007, respectively. The main factors used for modeling were year, area, quarter, gear and ratio between swordfish and blue shark catches. The significant models explained around 80% and 40% of the CPUE variability for both species, respectively. As in the case of the Atlantic swordfish, an important fraction of the variability in the blue shark CPUE was attributed to the targeting criteria of the skipper represented by the ratio between the two most prevalent species in the landings. Other less important factors, were also identified as significant for this species. The area was identified as the most relevant factor to explain the CPUE variability in the shortfin mako. The standardized CPUEs obtained for both species generally suggest that the trend in the two Atlantic 'stocks' of each species was quite stable during the periods considered.

Mohan, J. A., Miller, N. R., Herzka, S. Z., Sosa-Nishizaki, O., Kohin, S., Dewar, H., . . . Wells, R. J. D. (2018). Elements of Time and Place: Manganese and Barium in Shark Vertebrae Reflect Age and Upwelling Histories. *Proceedings of the Royal Biology Society B, 285*(1890) https://doi.org/10.1098/rspb.2018.1760

As upper-level predators, sharks are important for maintaining marine food web structure, but populations are threatened by fishery exploitation. Sustainable management of shark populations requires improved understanding of migration patterns and population demographics, which has traditionally been sought through physical and/or electronic tagging studies. The application of natural tags such as elemental variations in mineralized band pairs of elasmobranch vertebrae cartilage could also reveal endogenous and exogenous processes experienced by sharks throughout their life histories. Here, elemental profiles were characterized in vertebrae encompassing complete life histories (birth-to-death) of shortfin mako (*Isurus oxyrinchus*), common thresher (*Alopias vulpinus*) and blue shark (*Prionace glauca*) of known tag and recapture locations in the eastern North Pacific Ocean. All sharks were injected with oxytetracycline at initial capture, released and subsequently recaptured, with individual liberty times ranging from 215 days to 6 years. Vertebral band pairs forming over the liberty intervals were verified by counting the number of band pairs deposited since the oxytetracycline band. Regular oscillations in vertebrae manganese (Mn) content corresponded well with the number of validated band pairs, suggesting that Mn variation could be used to age sharks. Increases in vertebrae barium concentration were correlated with times when individuals occupied areas with high coastal upwelling indices, the timing and spatial intensity of which varied from year to year. Interspecific relationships were probably influenced by behavioural differences in horizontal and vertical habitat use, feeding habits and thermoregulatory physiology. These results indicate that vertebral sclerochronology has the potential to advance our knowledge of elasmobranch life history including age and growth estimation and environmental reconstruction.

Mourato, B. L., Amorim, A. F., & Arfelli, C. A. (2008). Standardized Catch Rate of Shortfin Mako (*Isurus oxyrinchus*) and Bigeye Thresher (*Alopias superciliosus*) Caught by São Paulo Longliners Off Southern Brazil. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 62*(5), 1542-1552 Retrieved from https://www.iccat.int/Documents/CVSP/CV062_2008/n_5/CV062051542.pdf

The CPUE must be standardized in order to gather estimations that potentially could be used as indexes of relative abundance. The standardized CPUE of shortfin mako (*Isurus oxyrinchus*) and bigeye thresher (*Alopias superciliosus*) sharks was estimated from the data of the Santos and Guaruja tuna longline fishery that operated in the southwest Atlantic from 1971 to 2006. The modeling procedures followed a Generalized Linear Model (GLM) approach assuming a log-normal error distribution. The final model included "year", "quarter" and "target" as main factors. For the both species the deviance analysis showed that the "year" factor was the most significant followed by "target" and "quarter" factors. As a result, the CPUE gradually decreased for the shortfin mako shark from 1971 to 2006 and showed a slight decline for the bigeye thresher shark from 1978 to 2006.

Mucientes, G., & Queiroz, N. (2019). Presence of Plastic Debris and Retained Fishing Hooks in Oceanic Sharks. *Marine Polluttion Bulletin, 143*, 6-11 https://doi.org/10.1016/j.marpolbul.2019.04.028

In a context where the problem of plastic pollution is globally increasing, more studies are needed to assess the real impact in oceanic megafauna. Here, we reported on the incidence of plastic and also retained hooks in two species of commercially exploited pelagic sharks in two ocean basins, the North Atlantic and South Pacific. In the South Pacific, 1.18% of caught blue sharks were observed with plastic debris on their body and 4.82% and with retained hooks, while 0.00% of shortfin makos had plastic debris and 1.76% were recorded with retained hooks. In the North Atlantic, 0.21% of blue sharks had plastic debris and 0.37% of blue, and 0.78% of shortfin makos were observed with retained hooks.

Neto, D. G., Dos Santos, R. S., Maracini, P., Caltabellotta, F. P., & Gadig, O. B. F. (2013). Strandings of the Shortfin Mako and the Pelagic Stingray on the Coast of Sao Paulo State, Southeastern Brazil: Report of Cases. *Boletim Do Instituto De Pesca, 39*(2), 187-194 Retrieved from https://www.pesca.sp.gov.br/boletim/index.php/bip/article/view/990

Strandings of oceanic-pelagic elasmobranchs in the southeastern Brazil are reported. Data comes from animals observed in the coast of Sao Paulo state, between 1999 and 2012. Nine individuals of two species were recorded: Pteroplatytrygon violacea (n = 5; mostly during the winter) and *Isurus oxyrinchus* (n = 4; two in the winter and two in the summer). For P. violacea the strandings restricted to the austral winter suggest that the species follows the intrusion of high temperatures water masses recorded in southeastern Brazil during this season, bringing some individuals to shallow waters. For *I. oxyrinchus* is possible that individuals escaped from hooks of the commercial pelagic longline fishery and suffered injuries in the esophagus and in the gastric wall, stranding due to difficulties in locomotion and feeding. As these stranded sharks were not necropsied and only two animals were observed during the austral summer, we cannot exclude other causes of beaching such diseases or the intrusion of cold water masses in the continental shelf during this season.

O'Brien, J. W., & Sunada, J. S. (1994). A Review of the Southern California Experimental Drift Longline Fishery for Sharks, 1988-1991. *Reports of California Cooperative Oceanic Fisheries Investigations, 35*, 222-229 Retrieved from http://calcofi.org/publications/calcofireports/v35/Vol_35_OBrien___Sunada.pdf

In 1988 the California Fish and Game Commission authorized an experimental drift longline fishery with a number of restrictions to a select group of commercial longline fishermen. Target species were shortfin mako shark (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*). During the first two years of this fishery, Department of Fish and Game personnel observed 19% of all fishing operations. Blue sharks and shortfin mako sharks accounted for approximately 91% of the catch, with blue sharks approximately twice as common as shortfin mako sharks. Shortfin mako shark catch per unit of effort (CPUE) changed little during the first two seasons, declined in the third season, then increased sharply in the fourth season. CPUE generally peaked in July and August. No striped marlin (*Tetrapturus audax*) were observed in the catch, and bycatch of other species was minimal. Length-frequency distributions of shortfin mako sharks exhibited two primary modes believed to represent ages two and three, indicating that the fishery harvested mostly juveniles.

O'Farrell, H. B. (2021). *Modeling Shark Bycatch Mitigation Strategies in Longline Fisheries.* (Doctor of Philosophy (PhD)), University of Miami, Retrieved from https://scholarship.miami.edu/esploro/outputs/doctoral/Modeling-Shark-Bycatch-Mitigation-Strategies-in-Longline-Fisheries/991031547888702976

This dissertation uses various modelling approaches to evaluate methods to reduce shark bycatch in the U.S. Atlantic pelagic longline and Gulf of Mexico (GOM) bottom longline fisheries. Combinations of environmental and gear variables are used to parameterize models to predict where and under what conditions bycatch occurs and propose bycatch mitigation strategies. All work uses NOAA NMFS observer datasets for U.S. commercial longline fleets operating in the Atlantic and/or Gulf of Mexico (GOM). Several statistical models are used to identify environmental conditions, regions and fishing methods that favor high bycatch of the overfished shortfin mako shark, *Isurus oxyrinchus*, based on the outputs of the delta-lognormal model and quantile regression of the upper quantiles. The results suggest that using the binomial portion of the delta-lognormal model, the probability of positive catch, to define a hot set basis for a “no fish” algorithm. Second, an individual based movement model is used to test three closure scenarios: stationary, seasonal, and moving weekly closures, for their ability to decrease shortfin mako incidental catch while minimizing the impact on the target fishery. Results suggest that any of the tested closures have potential to improve rebuilding when compared to the status quo. While the two moving closures give some reprieve to the population when compared to current fishing practices, the varying success and failure to surpass the stationary closure indicated that the time scale of a moving closure is very important, and a mismatch can dampen the benefits of the closure. The dissertation finishes with consideration of how to mitigate bycatch of 12 commonly caught shark species in the GOM reef bottom longline fishery including: blacknose, nurse, Atlantic sharpnose, scalloped hammerhead, sandbar, smooth dogfish, night, blacktip, silky, tiger, bigeye sixgill, and sevengill sharks. Catch rates of each species are modeled as a function of environmental and gear variables individually and all combined, as well as grouped by similar ecology. Gear and behavior variables were the most consistently retained in the best predictive models across all species and were the only variables with the potential to be used for a single rule that could decrease bycatch across all studied species. Patterns of environmental variables were only consistent across species with similar ecology

and habitat. For both the shortfin mako shark and bottom longline examples, we found that environmental conditions and gear configurations can be used to predict shark bycatch well enough to suggest bycatch mitigation strategies that significantly reduce shark bycatch in longline fisheries; however, there are tradeoffs involved in minimizing bycatch of multiple species, and minimizing bycatch while not unduly restricting target species catch.

Orelis-Ribeiro, R., Ruiz, C. F., Curran, S. S., & Bullard, S. A. (2013). Blood Flukes (Digenea: Aporocotylidae) of Epipelagic Lamniforms: Redescription of Hyperandrotrema Cetorhini from Basking Shark (*Cetorhinus maximus*) and Description of a New Congener from Shortfin Mako Shark (*Isurus oxyrinchus*) Off Alabama. *Journal of Parasitology, 99*(5), 835-846 https://doi.org/10.1645/12-125.1

We emend the original generic diagnosis for Hyperandrotrema Maillard and Ktari, 1978 , and redescribe its type species Hyperandrotrema cetorhini Maillard and Ktari, 1978 (Digenea: Aporocotylidae Odhner, 1912), based on the holotype and 2 paratypes collected from the heart of basking shark (*Cetorhinus maximus*). We also describe Hyperandrotrema walterboegeri Orelis-Ribeiro and Bullard n. sp. based on light and scanning electron microscopy of 6 adult specimens collected from the heart of a shortfin mako shark (*Isurus oxyrinchus* Rafinesque, 1810) captured from Viosca Knoll (29 degrees 11.70'N, 88 degrees 33.32'W; 123 km southwest of Dauphin Island, Alabama), northern Gulf of Mexico. *Hyperandrotrema spp*. infect lamniforms and differ from all other nominal aporocotylids at least by having a ventrolateral field of robust C-shaped spines (rather than transverse rows of minute, shaft-like spines), an inverse U-shaped intestine with extremely elongate ceca terminating near the level of the excretory bladder, and a common genital pore that comprises the dorsal opening of a common genital atrium. Adults of the new species exceeded 12 mm in total length, making them the largest of the nominal fish blood flukes. The new species further differs from *H. cetorhini* by the combination of having an adult body that is 7-8 times longer than wide, large midbody tegumental spines measuring 25-38 mum long x 10-12 mum wide, a long vas deferens 4-5% of the body length, a testis 9-11 times longer than wide, and a large ootype 105-150 mum long x 85-105 mum wide. This is the first report of Hyperandrotrema from the Gulf of Mexico and the second aporocotylid species reported from an epipelagic elasmobranch. Our results demonstrate that ecologically related (epipelagic, marine) and phylogenetically related (Lamniformes) definitive hosts are infected by morphologically similar (congeneric) fish blood flukes.

Otway, N. M. (2020). Capture-Induced Exertional Rhabdomyolysis in the Shortfin Mako Shark, *Isurus oxyrinchus*. *Vet Clin Pathol, 49*(1), 23-41 https://doi.org/10.1111/vcp.12824

BACKGROUND: Shortfin Mako sharks (*Isurus oxyrinchus*) are top-order predators in oceanic food chains. They are captured worldwide by commercial and recreational fisheries, but little is known about the effects that fishing has on the homeostasis and longevity of these animals. OBJECTIVE: This study aimed to assess the health of Shortfin Mako sharks captured by recreational fishers off eastern Australia. METHODS: Twenty-four sharks were captured, and their gender, length, weight, reproductive maturity, and stage were recorded. After blood and urine collection, serum analytes were quantified using standard biochemical methods, whereas urine was analyzed using semi-quantitative reagent strips, microscopic examination, centrifugation, and ammonium sulfate precipitation tests. RESULTS: Six Makos presented with red-brown urine. The means of notable serum analytes were as follows: sodium 276 mmol/L, potassium 15.6 mmol/L, inorganic phosphate 10.6 mmol/L, magnesium 3.3 mmol/L, urea 325 mmol/L, creatinine 52 mumol/L, AST 2806 U/L, CK 240938 U/L, lactate 44.4 mmol/L, osmolarity 1160

mmol/L, and pH 7.13. These analytes differed from the respective sand tiger shark reference interval, which was used as a proxy for Makos. The red-brown urine was due to myoglobin and had a mean pH of 5.76 that, when combined with red-brown casts, led to a diagnosis of fishing-induced exertional rhabdomyolysis that occurred secondary to lactic acidosis, hypoxia, and hypovolemia. It was further exacerbated by hyperkalemia and acute renal failure, serious complications that often lead to mortality. CONCLUSIONS: Practitioners caring for sharks and rays should consider collecting urine from free-living or aquarium animals when they are captured for examination and/or treatment, particularly at times with maximal seawater temperatures.

Panayiotou, N., Porsmoguer, S. B., Moutopoulos, D. K., & Lloret, J. (2020). Offshore Recreational Fisheries of Large Vulnerable Sharks and Teleost Fish in the Mediterranean Sea: First Information on Species Caught. *Mediterranean Marine Science, 21*(1), 222-227 https://doi.org/10.12681/mms.21938

Large-sized pelagic sharks and teleost fish are vulnerable to overexploitation by professional fisheries. To date, however, little is known about the species caught through recreational fishing. The aim of this study is to assess the catch of pelagic sharks and teleost fish in the Mediterranean Sea by recreational fishermen through an analysis of publicly available videos posted on social media. Results revealed that several vulnerable species are caught by offshore recreational fishermen: blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), thresher shark (*Alopias vulpinus*), sixgill shark (*Hexanchus griseus*), swordfish (*Xiphias gladius*), and Mediterranean spearfish (*Tetrapturus belone*). The most commonly caught species are blue shark and swordfish, the majority of which are juvenile and released back to sea. This paper proposes new measures for handling practices in order to protect these species.

Penades-Suay, J., Tomas, J., Merchan, M., & Aznar, F. J. (2017). Intestinal Helminth Fauna of the Shortfin Mako *Isurus oxyrinchus* (Elasmobranchii: Lamnidae) in the Northeast Atlantic Ocean. *Diseases of Aquatic Organisms, 123*(1), 45-54 https://doi.org/10.3354/dao03081

Large oceanic sharks represent a suitable model to investigate the influence of a host's oceanic conditions on the structure of its helminth communities. In this study, we describe the intestinal helminth fauna, and investigate determinants of infracommunity structure, in 39 specimens of shortfin mako *Isurus oxyrinchus* collected in the NE Atlantic. Six cestode species were found in the spiral valve of makos: 3 are typical from lamnid sharks, namely, gravid specimens of *Clistobothrium montaukensis*, *Gymnorhynchus isuri* and *Ceratobothrium xanthocephalum*, and 3 are immature specimens of cestode species common to several elasmobranchs, namely, *Dinobothrium septaria*, *Nybelinia lingualis*, and *Phyllobothrium cf. lactuca*. In addition, L3 larvae of *Anisakis sp*. type I were detected. Infracommunities were species poor and had low total helminth abundance. The result of Schluter's variance ratio test was compatible with the hypothesis of independent colonization of helminth taxa. These results conform to previous studies on oceanic predators that have hypothesized that these hosts should have depauperate and unpredictable helminth infracommunities because oceanic conditions hamper parasite transmission. However, mean species richness and mean total abundance of cestodes of shortfin mako and other oceanic sharks did not significantly differ from those of elasmobranchs from other habitats. This suggests that the large body size and prey consumption rates of oceanic sharks offset the negative 'dilution' effect of oceanic habitat on transmission rates. Additionally, or alternatively, parasites of oceanic sharks may have expanded the use of intermediate hosts through the trophic web to spread out the risk of failure to complete their life cycles.

Petersen, S. L., Honig, M. B., Ryan, P. G., Underhill, L. G., & Compagno, L. J. V. (2009). Pelagic Shark Bycatch in the Tuna- and Swordfish-Directed Longline Fishery Off Southern Africa. *African Journal of Marine Science, 31*(2), 215-225 https://doi.org/10.2989/Ajms.2009.31.2.9.881

The capture of pelagic sharks as bycatch of the South African pelagic longline fleet targeting tuna Thunnus spp. and swordfish *Xiphias gladius* was investigated during the period 1998-2005. In all, 26 species were caught, of which six are listed by the International Union for Conservation of Nature (IUCN) as Vulnerable and one (scalloped hammerhead *Sphyrna lewini*) as Endangered. Blue shark *Prionace glauca* and short-finned mako *Isurus oxyrinchus* were the most commonly caught species (69.2% and 17.2% respectively). Generalised linear models explained 70.4% of blue shark and 22.2% of short-finned mako bycatch patterns and showed that vessel name was the most important explanatory variable. Other significant explanatory variables included month, year, area, bathymetry, bait type, moon phase and time of set. South African-flagged, swordfish-directed vessels caught more sharks (11.7 blue sharks and 1.4 short-finned mako sharks per 1 000 hooks) than Asian-flagged, tuna-directed vessels (1.8 blue sharks and 0.9 short-finned mako per 1 000 hooks). The catch per unit effort of blue sharks and short-finned mako sharks started to decrease from 2001 and 2000 respectively. This was accompanied by a decrease in average length for both species over the period 2002-2007. Three techniques for extrapolating total shark mortality were investigated. Simple extrapolation yielded an estimate of 73 500 sharks per year; if vessel flag was taken into account, the estimate decreased to 39 200 sharks per year and to 43 100 sharks if vessel flag and area (5 grid cells) were taken into account.

Queiroz, N., Humphries, N. E., Mucientes, G., Hammerschlag, N., Lima, F. P., Scales, K. L., . . . Sims, D. W. (2016). Ocean-Wide Tracking of Pelagic Sharks Reveals Extent of Overlap with Longline Fishing Hotspots. *National Academy of Sciences, 113*(6), 1582-1587 https://doi.org/10.1073/pnas.1510090113

Overfishing is arguably the greatest ecological threat facing the oceans, yet catches of many highly migratory fishes including oceanic sharks remain largely unregulated with poor monitoring and data reporting. Oceanic shark conservation is hampered by basic knowledge gaps about where sharks aggregate across population ranges and precisely where they overlap with fishers. Using satellite tracking data from six shark species across the North Atlantic, we show that pelagic sharks occupy predictable habitat hotspots of high space use. Movement modeling showed sharks preferred habitats characterized by strong sea surface-temperature gradients (fronts) over other available habitats. However, simultaneous Global Positioning System (GPS) tracking of the entire Spanish and Portuguese longline-vessel fishing fleets show an 80% overlap of fished areas with hotspots, potentially increasing shark susceptibility to fishing exploitation. Regions of high overlap between oceanic tagged sharks and longliners included the North Atlantic Current/Labrador Current convergence zone and the Mid-Atlantic Ridge southwest of the Azores. In these main regions, and subareas within them, shark/vessel co-occurrence was spatially and temporally persistent between years, highlighting how broadly the fishing exploitation efficiently "tracks" oceanic sharks within their space-use hotspots year-round. Given this intense focus of longliners on shark hotspots, our study argues the need for international catch limits for pelagic sharks and identifies a future role of combining fine-scale fish and vessel telemetry to inform the ocean-scale management of fisheries.

Ramirez, K., Ovideo, J. L., & Gonzalez, L. (2009). [Shortfin Mako and Blue Shark by-Catch by the Mexican Longline Fleet Dedicated to Yellowfin Tuna Fishing in the Gulf of Mexico During 1994-2007]. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 64*(5), 1632-1643 Retrieved from http://www.iccat.int/Documents/CVSP/CV064_2009/no_5/CV0640501632.pdf

This document presents the information obtained from fishing trips of the Mexican longline fleet that catches yellowfin tuna (Thunnus albacares) in the Gulf of Mexico, with an observer onboard during 1994-2007. According to the results obtained, the Mexican longline fleet conducted 4,416 fishing trips, catching 1,127 shortfin mako (*Isurus oxyrinchus*) individuals as by-catch and 61 blue shark (*Prionace glauca*) individuals, being 1995 the year in which the highest number of individuals were recorded for both species in the 1994-2007 period. The size frequency for shortfin mako was represented by 70 to 411cm intervals of FL and 107 to 330cm FL for blue shark. The time-strata distribution of by-catch (kg) indicates that there were shortfin mako species every year with wide distribution patterns. Although there were less in the case of blue shark, they present a wide distribution pattern in the Exclusive Economic Zone of the Gulf of Mexico. The nominal CPUE (number of individuals/100 hooks) indicates that the catches are minimum for both species during the period and area studied, which concludes that longline fishing targetting yellowfin tuna in the Gulf of Mexico is sustainable.

Roxo, A., Mendes, S., & Correia, J. (2017). Portuguese Commercial Fisheries of Swordfish, *Xiphias gladius*. *Reviews in Fisheries Science & Aquaculture, 25*(2), 150-157 https://doi.org/10.1080/23308249.2016.1251879

Swordfish (*Xiphias gladius*) plays an important role in Portuguese fisheries. Portuguese commercial swordfish landings were analyzed from 1986 to 2012. Commercial landings of five incidental catches of pelagic sharks-bigeye thresher shark (*Alopias superciliosus*), thresher shark (*Alopias vulpinus*), shortfin mako shark (*Isurus oxyrinchus*), blue shark (*Prionace glauca*), and smooth hammerhead shark (*Sphyrna zygaena*)-were also evaluated for the same period. A total of 653 landings of swordfish (12,625 t) were observed in 62 ports. Annual landings for the fishery generally decreased over time, with a corresponding increase in price per kilogram. The most fished shark was blue shark, with 12,715 t in 48 ports. It was followed by shortfin mako, thresher, smooth hammerhead, and bigeye thresher (with 5113 t, 672 t, 19 t, and 0.45 t, respectively). Lowest landings of swordfish were observed in the first semester of each year, while catch levels of blue sharks were high during the same period. Shortfin mako catches did not raise until 2005. The remaining species studied always displayed lower landings, suggesting that most of them are bycaught.

Saidi, B., Echwikhi, K., Enajjar, S., Karaa, S., Jribi, I., & Bradai, M. N. (2020). Are Circle Hooks Effective Management Measures in the Pelagic Longline Fishery for Sharks in the Gulf of Gabès? *Aquatic Conservation: Marine and Freshwater Ecosystems, 30*(6), 1172-1181 https://doi.org/10.1002/aqc.3315

This study evaluated the circle hook use as a tool for shark management in the pelagic longline fishery in the Gulf of Gabes. The usual J-hook No. 2 with 10 degrees offset, which has been traditionally used by the fishery, was compared to the 18/0 non-offset circle hook in an alternating fashion along the main line. In total, 22 experimental longline sets were deployed through the shark fishing seasons of 2016 and 2017 to examine the effects of hook types on the catch composition, the catch rates, the hooking

location, and the status at haulback. The catch composition differed significantly among hook types. Moreover, an overall increase in catch rates for the main species, the sandbar shark *Carcharhinus plumbeus*, and the shortfin mako shark *Isurus oxyrinchus*, was observed when using circle hooks. There was no size-selective effect of circle hooks for the common species. The circle hooks were not effective at reducing at-haulback mortality of sandbar shark. Conversely, shortfin mako and smooth-hound shark *Mustelus mustelus* showed significantly lower relative mortality at haulback with circle hooks than with J-hooks. Furthermore, circle hooks were more frequently hooked externally than the J-hooks for the three shark species. Results demonstrated that the use of 18/0 non-offset circle hooks in the pelagic shark longline fishery can reduce mortality at haulback for some species without any benefit for the dominant species, the sandbar shark. Overall, it is difficult to promote the adoption of the use of circle hooks as a management measure in this specialized fishery. Management measures focusing on fishing effort controls, fishing closures in critical habitats, and size limits could have significant benefits for the conservation of shark species and may help to improve the sustainability of the shark fishery in the Gulf of Gabes.

Sales, G., Giffoni, B. B., Fiedler, F. N., Azevedo, V. G., Kotas, J. E., Swimmer, Y., & Bugoni, L. (2010). Circle Hook Effectiveness for the Mitigation of Sea Turtle Bycatch and Capture of Target Species in a Brazilian Pelagic Longline Fishery. *Aquatic Conservation-Marine and Freshwater Ecosystems, 20*(4), 428-436 https://doi.org/10.1002/aqc.1106

1. Incidental catches by the pelagic longline fishery is a major global threat for loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) sea turtles.
2. The reduction of incidental capture and post-release mortality of sea turtles in the Brazilian pelagic longline fishery, operating in the south-western Atlantic Ocean, was investigated by comparing the performance of 18/0 circle hooks with 9/0 J-type (control) hooks. Hook selectivity experiments were performed between 2004 and 2008, in a total of 26 trips, 229 sets and 145 828 hooks. The experimental design included alternating control and experimental hooks along sections of the mainline.
3. An overall decrease in capture rates for loggerhead turtles of 55% and for leatherbacks of 65% were observed when using circle hooks. In addition, deep-hooking in loggerheads decreased significantly from 25% using J-hooks to 5.8% with circle hooks, potentially increasing post-release survival.
4. Circle hooks increased catch rates of most of the main target species, including tunas (bigeye *Thunnus obesus* and albacore *T. alalunga*), and sharks (blue *Prionace glauca* and requiem sharks of the genus Carcharinus), with no difference in the capture rates of yellowfin tuna (*T. albacares*), shortfin mako shark (*Isurus oxyrinchus*), hammerhead sharks (*Sphyrna lewini* and *S. zygaena*), and dolphinfish or mahi mahi (*Coryphaena hippurus*). On the other hand, a significant decrease in the capture rate of swordfish (*Xiphias gladius*) was detected when using circle hooks.
5. Overall, results support the effectiveness of using circle hooks for the conservation of loggerhead and leatherback sea turtles, with positive effects on capture of most target species of the south-western Atlantic longline fishery.

Sellheim, N. (2020). The CITES Appendix Ii-Listing of Mako Sharks - Revisiting Counter Arguments. *Marine Policy, 115*, 103887 https://doi.org/10.1016/j.marpol.2020.103887

At the 18th Conference of the Parties of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in August 2019, shortfin and longfin mako sharks were listed on Appendix II. This listing now requires CITES parties to issue import and export permits and to closely monitor

international trade in mako products. In this paper, three core arguments are being revisited that were uttered against a listing of the mako shark: that it is not scientifically justifiable; that it will cause implementation problems and will have limited conservation success; and that regional fisheries management organisations (RFMOs) are better suited to manage mako sharks. It is concluded that while the mako is not yet endangered globally, the precautionary approach justifies its listing. At the same time, although there will in all likelihood be implementation problems, the overall effect of the listing will be positive. Lastly, given their limited scope and focus on utilisation of economically valuable species, RFMOs are not well-suited for the conservation of mako sharks.

Semba, Y., Matsumoto, T., Okamoto, H., & Tanabe, T. (2008). Report of Japan's Observer Program for the Tuna 2005 and 2006. *Collective volume of scientific papers. International Commission for the Conservation of Atlantic Tunas 62*(6), 2123-2145 Retrieved from http://www.iccat.int/Documents/CVSP/CV062_2008/no_6/CV062062123.pdf

This document reports the outline of the Japanese scientific observer program for longline fishery in the Atlantic Ocean conducted from August 2005 to March 2007. It also summarizes the data collected by this program. In 2005 fishing year (FY, thereafter, fishing year starts from August to next July), 504 operations and 1,343,789 hooks were observed. In 2006 FY, 378 operations and 981,021 hooks were observed. Majority of observation was conducted in the North Atlantic in both years. Number of observed species and individual number were 43 and 7,175 in 2005 FY. In fiscal 2006, 46 species and 10,621 individuals were observed. In the central and eastern North Atlantic, albacore and blue shark were dominant, while bluefin tuna were dominant in western North Atlantic. In general, most species examined were alive when they were brought up on the deck except for longbill spearfish. Regional difference in sex ratio was observed for many species. Especially, marked difference was observed for sharks (blue shark, porbeagle and shortfin mako shark). Length -frequency distribution showed regional difference in their modes and the size range for bluefin tuna, bigeye tuna, yellowfin tuna, longbill spearfish, blue shark and porbeagle. In general, large individuals occurred in tropical region except for bluefin tuna and porbeagle, for which difference between east and west was rather prominent.

Sherley, R. B., Winker, H., Rigby, C. L., Kyne, P. M., Pollom, R., Pacoureau, N., . . . Dulvy, N. K. (2019). Estimating IUCN Red List Population Reduction: Jara—a Decision-Support Tool Applied to Pelagic Sharks. *Conservation Letters, 13*(2) https://doi.org/10.1111/conl.12688

The International Union for Conservation of Nature's (IUCN) Red List is the global standard for quantifying extinction risk but assessing population reduction (criterion A) of wide-ranging, long-lived marine taxa remains difficult and controversial. We show how Bayesian state–space models (BSSM), coupled with expert knowledge at IUCN Red List workshops, can combine regional abundance data into indices of global population change. To illustrate our approach, we provide examples of the process to assess four circumglobal sharks with differing temporal and spatial datadeficiency: Blue Shark (*Prionace glauca*), Shortfin Mako (*Isurus oxyrinchus*), Dusky Shark (*Carcharhinus obscurus*), and Great Hammerhead (*Sphyrna mokarran*). For each species, the BSSM provided global population change estimates over three generation lengths bounded by uncertainty levels in intuitive outputs, enabling informed decisions on the status of each species. Integrating similar analyses into future workshops would help conservation practitioners ensure robust, consistent, and transparent Red List assessments for other long-lived, wide-ranging species.

Sims, D. W., Mucientes, G., & Queiroz, N. (2018). Shortfin Mako Sharks Threatened by Inaction. *Science, 359*(6382), 1342 https://doi.org/10.1126/science.aat0315

No abstract.

Sims, D. W., Mucientes, G., & Queiroz, N. (2021). Shortfin Mako Sharks Speeding to the Brink. *Science, 371*(6527), 355 https://doi.org/10.1126/science.abg2355

No abstract.

Stevens, J. D. (1992). Blue and Mako Shark by-Catch in the Japanese Longline Fishery Off South-Eastern Australia. *Australian Journal of Marine and Freshwater Research, 43*(1), 227-236 https://doi.org/10.1071/MF9920227

During the last 10 years, up to 70 Japanese longline vessels have fished Tasmanian waters of the Australian Fishing Zone each season, targeting bluefin tuna (*Thunnus maccoyii*). The average seasonal fishing effort in Tasmanian waters is about 3.3 million hooks, and data from observers suggests that this results in a by-catch of some 34 000 blue sharks (*Prionace glauca*) each year, representing a weight' Of about 275 tonnes. In the last few years, fishing effort has increased as the catch rates of southern bluefin tuna have declined. The sharks are discarded after removal of the fins. The actual number of blue sharks hooked is much higher than 34 000 because many are released by either shaking or cutting them off the line, although they are often damaged in the process. The majority of blue sharks caught are immature or adolescent females. Smaller numbers of shortfin mako sharks (*Isurus oxyrinchus*) are also caught and retained both for their fins and their meat. Tasmanian waters represent only one area of the Australian Fishing Zone fished by Japanese longliners.

Tsai, W.-P., Sun, C.-L., Wang, S.-P., & Liu, K.-M. (2011). Evaluating the Impacts of Uncertainty on the Estimation of Biological Reference Points for the Shortfin Mako Shark, *Isurus oxyrinchus*, in the North-Western Pacific Ocean. *Marine and Freshwater Research, 62*(12), 1383-1394 https://doi.org/10.1071/mf11010

Biological reference points (BRPs) are commonly used to assess the harvest level and stock status of marine fish populations. However, BRP estimates may be influenced by uncertainties about life-history parameters and fishing practices. The shortfin mako shark, *Isurus oxyrinchus*, is one of the most important by-catch species for tuna longline fisheries; however, its stock status remains poorly understood. To understand its population dynamics, the present study examined fishery statistics data and biological measurements of the shortfin mako in the north-western Pacific, and evaluated the impact of uncertainties associated with various sources of uncertainty, by using a simulation approach. The simulations indicated that BRPs are especially sensitive to changes in weight-length relationship and the growth parameters. Failure to take this into account may lead to inaccurate estimates and have serious consequences for management decision-making. To improve the accuracy of BRP estimates, biological measurements and life-history parameters should be updated regularly to account for changes in size composition and population structure. Further research could focus on increasing the sex-ratio sample size, updating the weight-length relationship and growth equations, incorporating

ageing error into BRP calculations and determining BRPs by using appropriate levels of spawning-potential ratio.

Tudela, S., Kai, A. K., Maynou, F., El Andalossi, M., & Guglielmi, P. (2005). Driftnet Fishing and Biodiversity Conservation: The Case Study of the Large-Scale Moroccan Driftnet Fleet Operating in the Alboran Sea (SW Mediterranean). *Biological Conservation, 121*(1), 65-78 https://doi.org/10.1016/j.biocon.2004.04.010

Illegal, large-scale driftnets are still used in several Mediterranean areas. According to international official sources, Morocco harbors the bulk of this fleet in the Mediterranean. To ascertain its biodiversity impact, 369 fishing operations (worth 4140 km of driftnets set) made by the driftnet fleet targeting swordfish (*Xiphias gladius*) based in Al Hoceima (Alboran Sea) were monitored between December 2002 and September 2003. Parallel surveys were made in the main Mediterranean ports and in that of Tangiers, in the Gibraltar Straits, to estimate the total fishing effort. Results showed an active driftnet fleet conservatively estimated at 177 units. Estimated average net length ranges from 6.5 to 7.1 km, depending on the port, though actual figures are suspected to be much higher (12-14 km). Most boats perform driftnet fishing all year round, resulting in very high annual effort levels. A total of 237 dolphins (short-beaked common dolphin, *Delphinus delphis*, and striped dolphin, *Stenella coeruleoalba*), 498 blue sharks (*Prionace glauca*), 542 shortfin makos (*Isurus oxyrinchus*) and 464 thresher sharks (*Alopias vulpinus*) were killed by the boats monitored during the sampling period, during the peak of the swordfish fishery, along with 2990 swordfish. Loggerhead turtle (*Caretta caretta*) was also caught (46 individuals). Estimates for a 12-month period by the whole driftnet fleet yielded 3110-4184 dolphins (both species) and 20,262-25,610 pelagic sharks distributed in roughly equal proportions for P. glauca, *I. oxyrinchus* and A. vulpinus, in the Alboran Sea alone; further 11,589-15,127 dolphins and 62,393-92,601 sharks would be killed annually around the Straits of Gibraltar. Dolphins suffer from annual take rates exceeding 10% of their population sizes in the Alboran Sea; this unsustainable impact is particularly worrying for D. delphis, because its last remnant healthy population in the Mediterranean occurs in this area. Average catch rate for swordfish, the main target species, amounted to only 0.8 individuals/km net set. Pelagic sharks are actively targeted by a part of the fleet.

Tuncer, S., & Kabasakal, H. (2016). Capture of a Juvenile Shortfin Mako Shark, *Isurus oxyrinchus* Rafininesque, 1810 (Chondrichthyes: Lamnidae) in the Bay of Edremit, Northern Aegean Sea (Turkey). *Annales. Anali za istrske in mediteranske studije. (Series historia naturalis), 26*(1), 31-36 https://doi.org/10.19233/ASHN.2016.5

A male shortfin mako shark (*Isurus oxyrinchus*) was caught on April 8, 2016, in the coastal waters of the Bay of Edremit by a commercial fisherman using nets set at the depths between 20 and 25 m. The specimen measured 74.7 cm in total length and weighed 2.75 kg. Its claspers were uncalcified, soft and shorter than the pelvic fins, revealing that it was a juvenile specimen. Upper and lower beaks of a cuttlefish (*Sepia officinalis*) were found in the stomach content. The nursery ground characteristics of *I. oxyrinchus* in relation to the feeding habit is also discussed.

Williams, E. H. (1978). Conchoderma Virgatum (Spengler) (Cirripedia Thoracica) in Association with Dinemoura Latifolia (Steenstrup & Lutken) (Copepoda, Caligidea), a Parasite of the Shortfin

Mako, *Isurus oxyrhynchus* Rafinesque (Pisces, Chondrichthyes). *Crustaceana, 34*(1), 109-110 Retrieved from http://www.jstor.org/stable/20103258

No abstract.

Yokota, K., Kiyota, M., & Okamura, H. (2009). Effect of Bait Species and Color on Sea Turtle Bycatch and Fish Catch in a Pelagic Longline Fishery. *Fisheries Research, 97*(1-2), 53-58 https://doi.org/10.1016/j.fishres.2009.01.003

The effects of bait species (mackerel and squid) and color (blue-dyed and non-dyed) on the loggerhead turtle *Caretta caretta* bycatch in a pelagic longline fishery in the western North Pacific were assessed in shallow-set longline fishing experiments. The loggerhead turtle catches were analyzed using a generalized linear model (GLM) with a Poisson distribution. The potential factors (bait species, bait color, other species catch, and sea surface temperature) affecting loggerhead turtle catch were incorporated as explanatory variables. The model analyses indicated that bait species affected loggerhead turtle catch, while bait color did not. The model predicted that catch rates of loggerhead turtles were 75% less on mackerel bait to squid bait. This study demonstrated that fish bait choice was very effective in reducing loggerhead turtle bycatch in pelagic longline fisheries, but that the use of blue-dyed bait was not. Similar model analyses were also performed on target and by-product fish species, such as swordfish *Xiphias gladius*, striped marlin *Tetrapturus audax*, bigeye tuna *Thunnus obesus*. blue shark *Prionace glauca*, and shortfin mako shark *Isurus oxyrinchus*, and other non-target species. The remarkable differences between bait species and color that were found for loggerhead turtles were not found for these species catches.