Improving Protections for Threatened Shark Nursery Grounds Off the Pacific Coast of Northwest Mexico

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1. Executive Summary

In 2021, The PEW Charitable trusts commissioned the Duke Marine Geospatial Ecology lab (MGEL) to conduct a literature review of existing scientific research on nursery and spawning grounds for a select group of threatened marine species. This project was developed with the following goals:

A) Identify a set of focal marine species that are of conservation concern.

B) Conduct a global-scale review of scientific literature to identify where nursery, pupping, and spawning grounds for these species are located, how these areas are impacted by fisheries and how they are protected by existing management measures.

C) Use this information to develop recommendations for how these areas can be protected more effectively to prevent further population declines.

Fundamentally, PEW intended this report to help determine how their own resources can be allocated most efficiently in the future to maximize conservation benefits, both in terms of where new initiatives should be located and what they will work to achieve. The following report is a supplementary document to the global MGEL study that helps further this underlying goal by providing a more focused analysis of an area with outstanding conservation importance identified in the global review: the coastal waters of northwest Mexico. By incorporating data from the literature review and additional research, this study develops more detailed recommendations for this area within the original project framework.

The first section explains why protecting shark nursery grounds is a critical conservation concern, especially in the northwest Mexican Pacific (NMP). Nursery grounds facilitate growth and development of juveniles, allowing them to reach the spawning stage. However, when fishers land large volumes of juvenile sharks, they accelerate population declines by eliminating the specimens themselves and their potential offspring, a prevalent problem in the NMP. Because nursery grounds for multiple threatened shark species in this area are targeted directly by artisanal fishers, reducing or eliminating these fishing threats will be critical to ensuring the survival of underlying populations.

The following two sections define the species composition and spatial distribution of focal shark nursery grounds in the NMP while identifying proximal fishing threats. Protecting juvenile shark aggregations requires a consideration of how they are distributed across the study area. Based on the literature review data, focal shark nursery grounds are concentrated in three specific regions of the NMP, which likely hold disproportionate conservation importance. While existing research is limited, available data suggests that all three regions are subject to concentrated fishing activity.

The next section outlines the existing regulatory framework for the NMP shark fishery. Understanding this regulatory framework is necessary to develop realistic and effective management recommendations that are within the purview of existing regulatory bodies. Two central regulatory bodies are identified, both of which have authority to institute new protection measures for local shark nursery grounds.

The final two sections synthesize the preceding research to provide recommendations for how the Mexican government can protect focal shark nursery grounds in the NMP more effectively. Recording the species composition and corresponding locations of juvenile shark landings in logbook reports can inform the placement of new, small-scale area closures, a feasible means of protecting these nursery grounds from artisanal fishing. The conclusion further outlines how non-governmental organizations (NGOs) like PEW can collaborate with the Mexican government to ensure the success of these new measures.

2. Introduction

2.1 Conservation Importance of Shark Nursery Grounds

Since the 1950s, overfishing and bycatch loss has led to the depletion of a variety of marine species across the globe. As population declines continue, protecting nursery grounds for these species will become an increasingly important management tool for preventing extinctions and facilitating population growth. Although specific definitions of a "nursery ground" vary among marine biologists, they are broadly defined as areas where juveniles repeatedly congregate to grow and develop after the spawning period (Heupel 2007). The survival of juvenile aggregations within these areas is critical to the future resilience of underlying populations, as their eventual ability to spawn is the only mechanism compensating for losses related to fishing.

However, these characteristics also make nursery grounds an attractive target for local fishers because the timing and location of juvenile congregations within them is predictable. Instead of spending time and money searching for more dispered adult specimens, fishers can quickly and efficiently land a large number of juvenile fish at once (Russell et al. 2012). Through this process, fishers disproportionately reduce future population size by eliminating the individuals themselves and the offspring they would have produced. Conversely, reducing or eliminating fishing activity in nursery grounds facilitates population growth and recovery by increasing future reproductive capacity.

Protecting shark nursery grounds, in particular, represents a critical conservation initiative. Over the past 50 years, directed fishing for the Asian fin industry and bycatch interactions have led to widespread shark losses. Through both of these mechanisms, global shark populations have declined by approximately 71% since 1970 (Pacoureau et al. 2021). The life-cycle patterns of most sharks also make them especially vulnerable to overfishing. Most shark species have long maturation periods, increasing the probability of mortality before spawning occurs (Ketchum et al. 2020). Sharks also have relatively low fecundity compared to other marine species, preventing surviving spawners from compensating for juvenile losses (Tamburin et al. 2019). Both of these traits exacerbate reductions in reproductive capacity related to fishing in nursery areas. Thus, actively eliminating fishing threats from shark nursery grounds is necessary to ensure the survival of underlying populations.

2.2 Study Area Background

The NMP represents an important example of why these initiatives are urgently needed. These coastal waters contain exceptional biodiversity, with at least 53 different shark species inhabiting waters off the west coast of Baja California and Baja California Sur (Ramirez-Amaro et al. 2013). Although existing scientific research on most of these populations remains sparse or non-existent, available data suggest that juveniles from at least seven of these species rely on nursery grounds within this area to grow and mature (Kot et al. 2022). All seven also face significant extinction risk, making their nursery grounds especially important from a conservation perspective.

Despite the ecological importance of these areas, Mexican longline vessels continue to land large volumes of juvenile sharks from the NMP. Mexico consistently ranks within the top five shark-producing nations across the globe, with around 75% of annual landings coming from the Pacific coast (Santana-Morales et al. 2020). While these catch volumes are significant, the boats landing them are predominantly small-scale; approximately 80% of total shark landings in Mexico are conducted by artisanal panga vessels between five and eight meters in length

(Cartamil et al. 2011; Ramirez-Amaro et al. 2013). In the more productive Pacific region, these artisanal vessels are also concentrated along the northern coastline (Sosa-Nishizaki et al. 2020). This overlap between intense fishing activity and diverse shark nursery grounds in the NMP has led to widespread juvenile losses of multiple threatened shark species, which the Mexican government has generally failed to mitigate or eliminate.

Despite the relative paucity of data on the spatial distribution of shark nursery grounds and fishery interactions in the NMP, this report synthesizes available information to develop new strategies for protecting these juvenile aggregations more effectively. Collectively, government landings records, existing scientific research and the unique enforcement challenges of this region suggest that a series of small-scale area closures will provide the most realistic and effective means of reducing juvenile losses for the seven focal shark species. Additionally, this report identifies research initiatives that will be necessary to ensure the success of new measures and fill critical data gaps that inhibit regulatory efforts.

3. Locations and Composition of Focal Shark Nursery Grounds in the NMP: Literature Review Results

3.1 Global-Scale Analysis: Background

The literature review conducted by MGEL in 2021 provides an extensive dataset that can be used to identify the locations of threatened shark nursery grounds across the globe. Of the 48 focal marine species considered in the MGEL study, 28 of them were shark species, which were chosen based on recent population trends and vulnerability to future collapse (Kot et al. 2022). For each of these species, MGEL conducted a review of existing scientific literature to determine where their spawning and nursery grounds are located within the Exclusive Economic Zones (EEZs) of specific countries and the global high seas area. Any information related to proximal fishing threats and existing protection measures was also recorded from each relevant source.

3.2 Global-Scale Analysis: Methodology

Defining the broad ecological importance of the focal shark nursery grounds in the NMP requires a consideration of the global context, which this literature review provides. However, utilizing any single metric from the global-scale data to determine the relative ecological importance of different regions is inherently problematic. For instance, from a conservation perspective, an area that contains nursery grounds for multiple threatened shark species seems intuitively more important than a similarly sized area with a nursery ground for only one shark species. In reality, however, the less diverse area may contain the only known nursery ground for that species, while the more diverse area may represent a relatively insignificant portion of a much larger nursery area or set of areas for the species that inhabit it.

Sampling biases may also affect data collection, inhibiting direct comparisons between specific locations. Many remote or inaccessible areas contain important spawning/nursery grounds, which may not be documented in the literature review due to lack of existing research (Kot et al. 2022). Thus, the global-scale data may not be suitable to identify areas that lack conservation importance, but it can be used to identify areas with properties that are valued from a conservation perspective.

The species diversity metric, in particular, provides a means of identifying regions that are likely to contribute to the future growth and stability of multiple shark populations. In areas

where multiple shark species utilize proximal locations as spawning/nursery habitats, even small-scale, localized fishing activity can affect a variety of different shark populations in disparate areas. While the conservation importance of a given nursery ground is not exclusively defined by the number of species within it, a single area-based protection measure within a highly diverse nursery ground can increase the resilience of multiple shark populations at once. Thus, identifying especially diverse shark nursery grounds provides an imperfect but justifiable means of focusing future shark conservation efforts, especially if these areas face significant fishing threats.
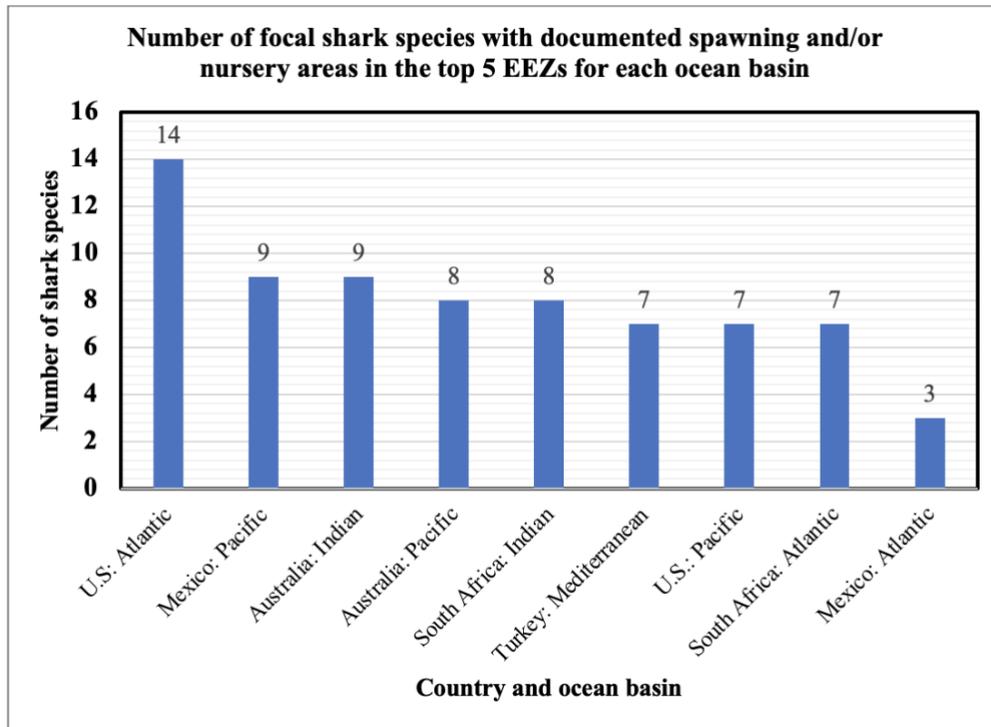
3.3 Global-Scale Analysis: Results

As Figure 1 shows, the EEZs of the U.S., Australia and Mexico contain spawning and/or nursery grounds for more focal shark species than the vast majority of other countries as well as the entire global "high seas" area beyond any national jurisdiction (Kot et al. 2022). In part, this result is likely due to the massive coastlines of these three countries, which all cover multiple ocean basins. While this disparity in overall EEZ size prevents relative comparisons between countries related to the degree of overlap across species, it still has important implications from a conservation perspective. Specifically, the components shaping shark conservation efforts in these three countries, such as fishing fleet characteristics, existing regulatory framework and enforcement capacity, likely have a disproportionate impact on a multitude of threatened shark populations across the globe, as a multitude of focal shark species rely on waters within their jurisdiction to grow and reproduce.

Figure 1**:** Total number of focal shark species with documented spawning and/or nursery grounds in each country EEZ (in green) and the high seas (in blue) from the MGEL literature review. While the EEZs of 59 countries contained spawning and/or nursery ground for at least one focal shark species, countries shown rank in the top 20 for overall species diversity (Kot et al. 2022).

Dividing the top five country EEZs by proximal ocean basin further illustrates the importance of the Mexican Pacific for the focal shark species considered in the MGEL literature review. As Figure 2 shows, the Mexican Pacific coast contains spawning and/or nursery grounds for at least nine of the 28 focal shark species, more than the entire Australian Indian coast, Australian Pacific coast, U.S. Pacfic coast, the global high seas area and the EEZs of at least 55 other coastal countries.

Figure 2: Total number of focal shark species with documented spawning and/or nursery grounds in each country EEZ, divided by ocean basin. Countries shown rank in the top five for overall number of focal shark species with relevant activities in their EEZ (Kot et al. 2022).

3.4 Regional Results: Species Composition and Extinction Risk

The NMP provides an ideal location for juvenile shark development, in part due to strong upwelling along the coast. Surface winds along the NMP coastline predominantly move southwest towards the equator, pushing surface waters offshore while allowing deeper, nutrient-rich waters to rise to the surface (Checkley and Barth 2009). This nutrient abundance facilitates strong primary productivity and growth of large coastal populations of smaller fish such as sardines and anchovies. These smaller fish, in turn, provide an abundant source of food for juvenile sharks, allowing them to grow and develop into later life stages (Saldana-Ruiz et al. 2019).

As a result of these conditions, the NMP contains documented nursery grounds for at least seven of the nine focal shark species with relevant activities along the Mexican Pacific coast, all of which face significant extinction risk as shown in Table 1. The International Union for Conservation of Nature (IUCN) Red List utilizes a variety of criteria to define the relative extinction risk of different species, such as: recent population fluctuations, current population

size and projected reproductive potential. Based on these criteria, species are grouped into one of the seven categories shown in Figure 3, with "Vulnerable," "Endangered" and "Critically Endangered" representing the most threatened catagories (IUCN Red List Catagories 2000).

As Table 1 shows, Shortfin Mako Sharks, which have multiple nursery grounds in the NMP, fall within the second highest "Threatened" category of "Endangered." IUCN projects that global Shortfin Mako populations will decline by approximately 46.6% over the next three generations (approximately 75 years), while populations in the northern Pacific will decline by approximately 36.5% by 2045 (Rigby et al. 2019b). These reductions could lead to complete population collapse, creating "a very high risk of extinction in the wild" according to IUCN (IUCN Red List Catagories 2000). The Convention on Migratory Species (CMS), a multi-national conservation group organized by the United Nations, also identifies Shortfin Mako as a global conservation concern. Specifically, Shortfin Mako are listed in Appendix 2 of the convention text, which identifies species that have an "unfavorable conservation status" and require concerted international effort to protect from further declines (CMS Appendix 1 and 2).

Common Thresher sharks, Great White Sharks, Silvertip Sharks and Smooth Hammerhead Sharks also face significant but slightly lower extinction risk according to IUCN. All 4 species are classified as "Vulnerable" with "a high risk of extinction in the wild," as shown in Table 1. IUCN projects that global Common Thresher Shark populations will decline by approximately 47% over the next three generations (approximately 75 years) and CMS lists them in Appendix 2 of the convention text (Rigby et al. 2019d; CMS Appendix 1 and 2). Similarly, IUCN projects that global Great White Shark populations will decline by 53.8% over the next three generations (approximately 159 years) (Rigby et al. 2019a). Notably, they are listed in Appendix 1 of the CMS text, which includes "migratory species that have been assessed as being in danger of extinction."
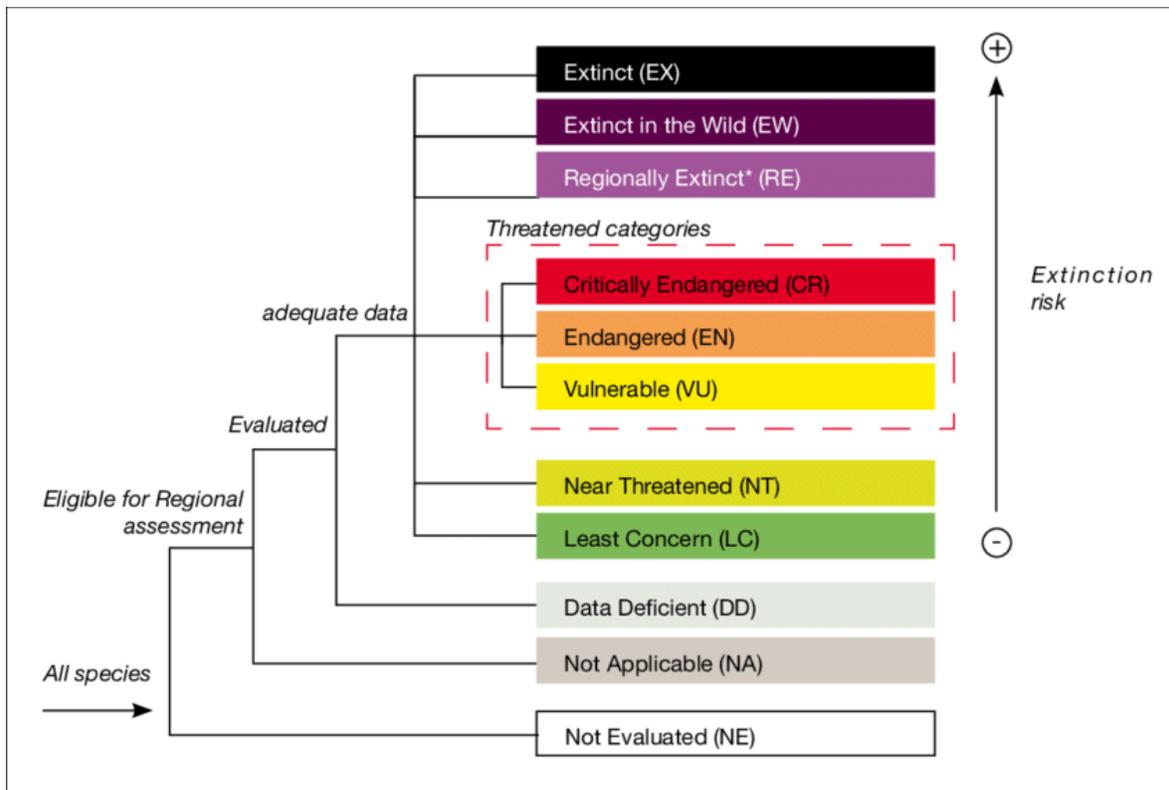
Over the next three generations, IUCN also projects that global Silvertip Shark populations will decline by over 30% while Smooth Hammerhead Shark populations will decline by 64.8% (Espinoza et al. 2021; Rigby et al. 2019c). While CMS does not identify either of these species as an international concern, these drastic declines could still pose a threat to the future survival of both species.

Although they may be less vulnerable than other focal shark species in the NMP, Blue Shark and Bluntnose Sixgill Sharks face significant extinction risk as well. As shown in Table 1, both species are classified as "Near Threatened" by IUCN, suggesting they are "likely to qualify for a threatened category in the near future." Blue Sharks are also listed in Appendix 2 of the CMS text.

Overall, CMS listings and/or IUCN classifications suggest that all seven focal shark species with documented nursery grounds in the NMP face a significant risk of extinction over the coming years, so reducing fishing pressures in these areas is a critical conservation initiative. Given the relative risk levels of each species and the projected decline of Shortfin Mako populations in the northern Pacific, future protection measures should also prioritize Shortfin Mako nursery grounds, as this species is exceptionally vulnerable.

Table 1: Summary of data from the MGEL literature review for the focal shark species with documented nursery grounds in the NMP.

Species Name	Common Name	IUCN Status	CMS listing	Activity	Location	# of References
Isurus oxyrinchus	Shortfin Mako Shark	Endangered	Appendix 2	Nursery	Waters off northern Baja California; Sebastian Vizcaino Bay; Waters off Baja California Sur	4
Prionace glauca	Blue Shark	Near Threatened	Appendix 2	Nursery	Waters off Baja California Sur	1
Alopias vulpinus	Common Thresher Shark	Vulnerable	Appendix 2	Nursery	Waters off northern Baja California; Sebastian Vizcaino Bay	6
Charcharhinus albimarginatus	Silvertip Shark	Vulnerable	N/A	Nursery	Waters off the Revillagigedo islands	1
Carcharodon carcharias	Great White Shark	Vulnerable	Appendix 1	Nursery	Waters off the Guadalupe Islands; Sebastian Vizcaino Bay	3
Hexanchus griseus	Bluntnose Sixgill Shark	Near Threatened	N/A	Nursery	Waters off southern Baja California Sur	1
Sphyrna zygaena	Smooth Hammerhead Shark	Vulnerable	N/A	Nursery	Sebastian Vizcaino Bay	1

Figure 3: IUCN Red List categories organized by relative extinction risk (IUCN Red List Catagories 2000).

3.5 Regional Results: Spatial Distribution of Focal Shark Nursery Grounds
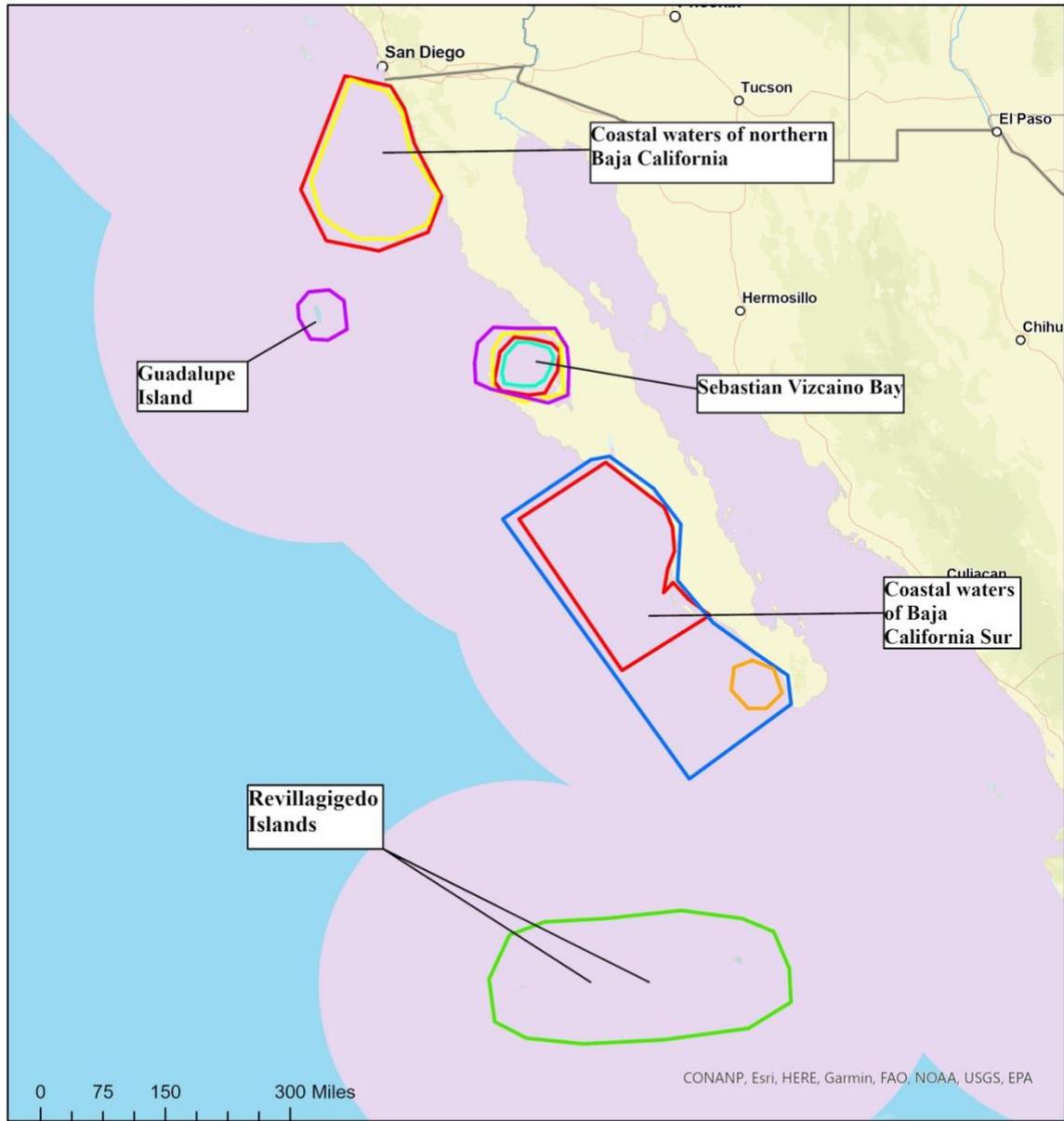
        Based on location data from the literature view, nursery grounds for the seven focal shark species in the NMP contain a high degree of overlap, suggesting that specific coastal areas within the NMP may hold disproportionate conservation importance. As Figure 4 illustrates, focal shark nursery grounds are concentrated in three areas: the southern edge of the Southern California Bight off the northwest coast of Baja California, Sebastian Vizcaino Bay and the coastal waters south of Laguna San Ignacio along western Baja California Sur.

        More specifically, the waters off northwest Baja California contain documented nursery grounds for Shortfin Mako and Common Thresher Sharks (Cartamil et al. 2010; Cartamil et al. 2016; Hight et al. 2007; Kinney et al. 2020; Mohan et al. 2018), while Sebastian Vizcaino Bay contains nursery grounds for the same two species as well as Great White and Smooth Hammerhead Sharks, as shown in Figure 4 (Conde-Moreno and Galvan-Magana 2006; Tamburin et al. 2019; Cartamil et al. 2011; Cartamil et al. 2016; Eduardo Becerril-Garcia et al. 2019; Tamburin et al. 2020; Felix-Lopez et al. 2019). The waters off Baja California Sur contain nursery grounds for Shortfin Mako, Blue Sharks and Bluntnose Sixgill Sharks (Ramirez-Amaro et al. 2013; Carrera-Fernandez 2010; Eduardo Becerril-Garcia et al. 2017). Additionally, Great White Sharks have a nursery ground in the waters surrounding Guadalupe Island (Alderete-Macal et al. 2020) and Silvertip Sharks have a nursery ground in the waters surrounding the Revillagigedo Islands (Le Croizier et al. 2020).

        While all of these areas represent critical nursery grounds for multiple threatened shark species, defining their relative ecological importance is more difficult. Sebastian Vizcaino Bay displays the most species overlap and highest number of vulnerable or endangered focal shark species, but all three overlap regions contain nursery grounds for endangered Shortfin Mako.

        Data deficiencies also inhibit relative comparisons between these areas. Through the literature review, only one relevant scientific paper was identified for Blue Sharks, Silvertip Sharks, Bluntnose Sixgill Sharks and Smooth Hammerhead Sharks, as shown in Table 1 (Kot et al. 2022). Given this lack of published research, many existing nursery grounds for these species may not be included in the map. Additionally, the location information provided in existing scientific papers was often imprecise, inhibiting finer-scale comparisons; instead of giving specific geographic coordinates, many papers define nursery areas based on their general proximity to a single geographic feature such as "south of Laguna Manuela." Thus, Figure 4 is not an exhaustive, precise representation of all relevant nursery grounds in the NMP, but it suggests that specific areas like Sebastian Vizcaino Bay may contribute disproportionately to the reproductive capacity and resilience of focal shark populations in the Pacific Ocean.

Shark Nursery Grounds in the NMP

Figure 4: Spatial distribution of nursery grounds documented in the literature review for the seven focal shark species. Areas shown approximate the most specific locations provided in the scientific literature.

4. Fishing Threats to Focal Shark Nursery Grounds in the NMP

4.1 Fleet Composition and Characteristics

The NMP shark fishing fleet is primarily composed of panga boats, which are outboard powered, 5 to 8 meter-long vessels that are only capable of travelling approximately 35 kilometers (km) from their home port (Cartamil et al. 2011). This range limits individual trips to a single day in near-coastal waters. To harvest sharks and other species, these vessels utilize longline gear, which is composed of a single mainline connected to around 350 hooks (Ramirez-Amaro et al. 2013). These hooks ensnare a variety of shark species indiscriminately, after which the fishers pull the mainline in by hand to recover the catch.
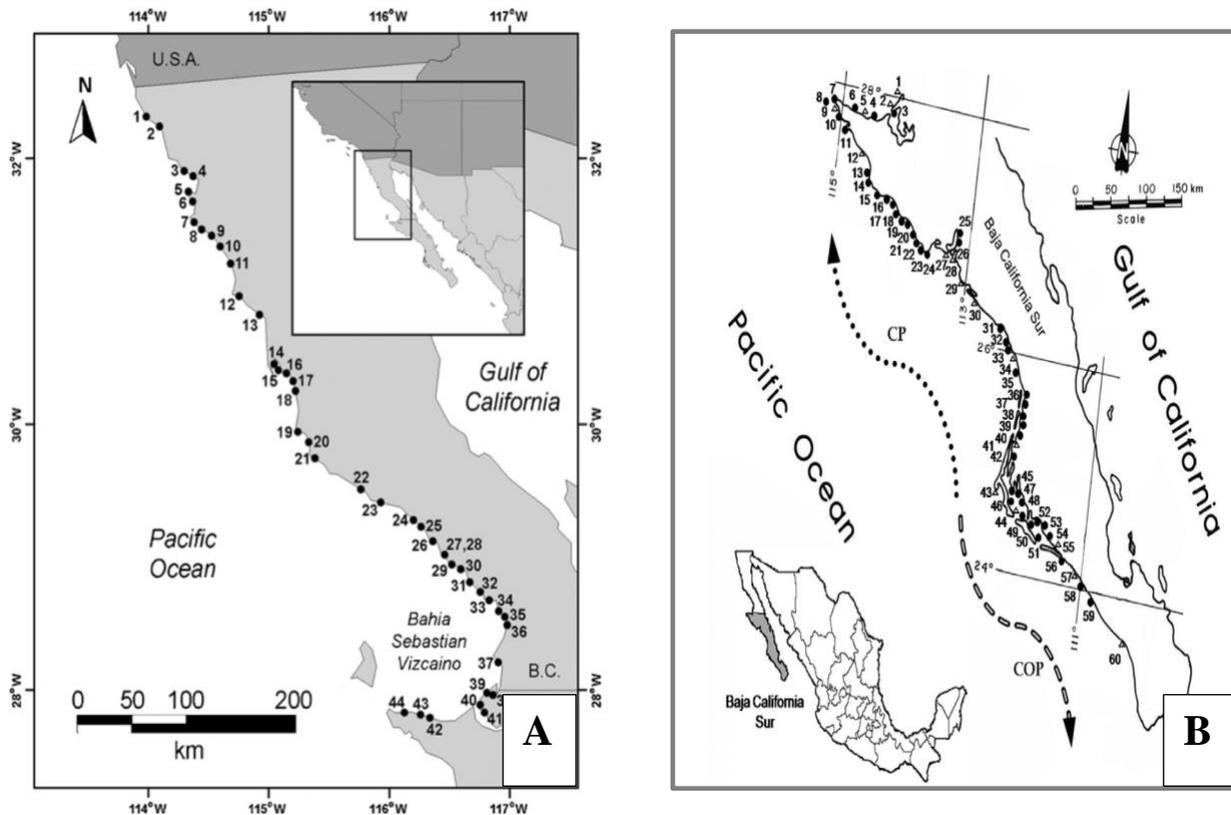
Although boat size and available fishing technologies limit individual production, this fleet collectively has an immense impact on coastal shark populations due to vast number of participating vessels. In 2017, for instance, 1,787 panga vessels were registered to catch sharks in the Mexican Pacific, with 1,623 of them based in the northern states of Baja California and Baja California Sur (Sosa-Nishizaki et al. 2020a). A vast array of unregistered, illegal vessels participate in the fishery as well. Between 1950-2010, for example, available research suggests that illegally caught shark landings in the Mexican Pacific were almost twice as large as total recorded landings from legal vessels (Sosa-Nishizaki et al. 2020a).

Given the predominance of illegal fishing, accurately measuring total shark landings from the NMP is extremely difficult, but official catch statistics suggest that total volumes have increased substantially in recent years. For instance, between 2013 and 2017, total recorded shark landings from the Pacific coast increased from 20,318 tons to 31,546 metric tons (Sosa-Nishizaki et al. 2020b). Because most registered vessels are based in northern states and have an extremely limited range, the vast majority of these sharks were likely recovered from waters in the NMP.

This artisanal fishery differs from most modern, industrialized fisheries in several fundamental characteristics. Firstly, instead of targeting specific species, these fishers generally catch sharks opportunistically, retaining the vast majority of their catch regardless of species or size (Cartamil et al. 2011). This strategy is facilitated by the existing regulatory framework, which allows fishers to retain every species except Whale Sharks, Great White Sharks and Basking Sharks with no size restrictions between August 1st and April 31st (DOF 2007). Secondly, instead of delivering their catch to a select set of centralized ports, these vessels return to a large number of small fishing camps that are widely distributed across the coastline, as shown in Figure 5. Cartamil et al. 2011 documented at least 44 distinct artisanal fishing camps along the Pacific coast of Baja California alone.

Finally, while the socioeconomic importance of the shark fishery in this area generally remains unresearched, landings likely provide a critical source of food and income for coastal fishing communities (Sosa-Nishizaki et al. 2020a; Cartamil et al. 2011). Sosa-Nishizaki et al. 2020a suggests that the vast majority of NMP shark landings are retained by local communities as a food source, which is commonly processed into a dried, salted product that is easily stored and preserved. While shark finning has been prohibited in Mexico since 2010, shark fins also remain a highly valuable commodity in illegal markets (Saldana-Ruiz et al. 2019). For instance, Santana-Morales et al. 2020 found that artisanal fishers can sell Blue Shark fins for between 28-50 dollars per kilogram, making the fins of an individual as valuable as the meat itself. Thus, while the extent of the illegal shark fin trade in Mexico is difficult to quantify, many artisanal fishers likely continue selling shark fins to illegal exporters. All of these characteristics pose

unique management and enforcement challenges that should be central considerations when developing new protection strategies for focal shark nursery grounds in the NMP.

Figure 5: A) Documented artisanal fishing camps along the western coast of Baja California from Cartamil et al. 2011. B) Documented artisanal fishing camps along the western coast of Baja California Sur from Ramirez-Amaro et al. 2013.

4.2 Data Deficiencies

Comprehensively quantifying the spatial distribution of shark fishing efforts and corresponding catch composition in the NMP is inherently challenging due to pervasive data deficiencies and inaccuracies. Unlike more industrialized fishing fleets, these vessels do not operate vessel monitoring systems (VMS) that track and record boat movements. Utilizing onboard government observers to document local fishing spots has also proven difficult given the sheer number of vessels, which require an immense amount of manpower to achieve significant coverage. Although the Mexican government instituted an onboard observer program in 2006, an average of only 5% of registered vessels have been observed annually between 2006-2020 (Saldana-Ruiz et al. 2019).

Since 2007, the Mexican government has required that registered shark fishers complete daily logbook entries, which include the total weight of each species landed. Although fishers are not required to report where these landings were caught, they must record the specific fishing camp they deliver to. In the NMP, these logbooks are then submitted to one of 14 local fisheries offices (LFOs) located along the western coast of Baja California and Baja California Sur, who

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compile monthly landings for their district and report total landed weight for each species to the Federal Fisheries Commission (Erisman et al. 2011).

While recording and compiling this data requires significant effort from fishers and government agencies, a variety of factors detract from it's accuracy. Firstly, fishers themselves are often unable to distinguish between species, prompting the LFOs to combine specific species into more general categories, such as all types of Hammerhead Shark (Sandana-Ruiz et al. 2010; Santana-Morales 2020). Critically, the sizes of landed specimens are not recorded. Local taxes and subsidies for artisanal fishers are also calculated using total landings volumes, which may incentivize deliberate under reporting. Additionally, the predominance of illegal fishing means that a large portion of total shark catches are not reported at all, decreasing the accuracy and utility of government landings records for research scientists.

Beyond government records, existing scientific research on shark fishing efforts remains highly limited. While a large body of existing research has studied fishing impacts on shark nursery grounds in the Gulf of California, since 2000, only four scientific studies have been conducted in the NMP that directly measure and record shark landings from artisanal vessels.

4.3 Fishing Interactions with Focal Shark Nursery Grounds: Scientific Data

A) Northwest Coast of Baja California

Despite these data gaps, existing scientific studies that directly sample artisanal landings suggest that juvenile focal shark specimens compose the vast majority of landings in the three overlap regions defined above. Between 2007-2009, Santana Morales et al. 2020 opportunistically collected a series of landings samples from the port of Ensenada. As predicted from the literature review data, juvenile Shortfin Mako and Common Thresher Sharks composed a significant portion of these samples. Specifically, as shown in Table 2, more than 95% of the 90 Shortfin Mako measured from collected samples were smaller than 200 cm in length, the threshold that distinguishes juveniles from adults. One hundred percent of the 43 measured Common Thresher Sharks were also smaller than their adult length threshold of 330 cm.

Notably, compared to Blue Shark specimens, Shortfin Mako and Common Thresher Sharks composed an insignificant portion of these landings samples from Ensenada. Shortfin Mako specimens only composed 3.71% of samples, while Common Threshers composed 1.32% (Santana Morales et al. 2020). Blue Sharks, in contrast, composed more than 93.54% of total samples by weight, with 4,893 specimens identified in collected samples. Critically, over 95% of the 1,496 measured Blue Shark specimens consisted of juveniles, as shown in Table 2. While the literature review did not document a Blue Shark nursery ground in this area, these data suggest that coastal waters around Ensenada contain large juvenile Blue Shark aggregations that are targeted by the artisanal fleet. Given the species and size compositions of these landings samples, proximal nursery grounds for Shortfin Mako, Common Thresher Sharks and Blue Sharks likely supply the vast majority of total catch for artisanal fishers in northwestern Baja California, with juvenile Blue Sharks facing the highest fishing pressure.

B) Sebastian Vizcaino Bay

Similar studies suggest that fishers around Sebastian Vizcaino Bay also rely on nearby focal shark nursery grounds to supply the vast majority of their catch. Between 2006-2008, Cartamil et al. 2011 opportunistically collected landings samples from Laguna Manuela, one of the largest artisanal fishing ports along Sebastian Vizcaino Bay. As shown in Table 2, at least 10

Shortfin Mako, Common Thresher Sharks, Great White Sharks, Smooth Hammerhead Sharks and Blue Sharks were measured from these samples, all of which were juveniles.

Coupled with these size measurements, the overall species composition of landings samples from this study suggests that juvenile Shortfin Mako and Blue Sharks compose the majority of artisanal landings from Sebastian Vizcaino Bay. Cartamil et al. 2011 identified 2,120 Blue Sharks, composing 68% of total sample weight, as well as 881 Shortfin Mako, composing 28% of total sample weight (Cartamil et al. 2011). Given that measured samples for these species were exclusively juveniles, the vast majority of total shark landings from Laguna Manuela likely consist of juvenile Blue Sharks and Shortfin Mako taken from proximal nursery grounds. Juvenile Common Thresher Sharks, Smooth Hammerhead Sharks and Great White Sharks likely compose a significant portion of landings as well. Notably, the literature review did not document a Blue Shark nursery ground in Sebastian Vizcaino Bay, but these data suggest that it contains one.

Additional studies confirm that many juvenile Great White Sharks are caught by fishers in Sebastian Vizcaino Bay. Using semi-structured interviews, Garcia-Rodriguez and Sosa-Nishizaki 2018 determined that 75% of the 75 participating fishers from this region have caught White Sharks. Importantly, sixty eight percent of these fishers reported that specimens less than 200 cm long were caught most frequently. Using a series of artisanal landings samples collected from the coast of Sebastian Vizcaino Bay between 1993 and 2013, Onate-Gonzales et al. 2017 also identified 353 White Sharks, which were exclusively composed of juveniles.

C) West Coast of Baja California Sur

The species and size composition of shark landings from Baja California Sur also reflects the species and size composition of nearby focal shark nursery grounds, again suggesting that these areas supply the majority of local shark landings. Between 2000-2010, Ramirez-Amaro et al. 2013 opportunistically collected landings samples from a series of artisanal camps along the central Pacific coast of Baja California Sur. Together, Blue Sharks and Shortfin Mako composed 91% of total samples, but Common Thresher Sharks and Smooth Hammerhead Sharks specimens were also identified. Measured specimens for all of these species consisted mostly of juveniles, as shown in Table 2. The predominance of juvenile Shortfin Mako and Blue Sharks, in particular, suggests that their nursery grounds are frequently targeted by fishers in this area. Importantly, while the literature review identified nursery ground for Shortfin Mako and Blue Sharks along Baja California Sur, juvenile Common Thresher Sharks and Smooth Hammerhead Sharks were not documented in this region. Thus, this southern nursery ground may also contain more focal shark species diversity than originally recorded in Figure 4.

Collectively, these results suggest that artisanal fishers rely on proximal focal shark nursery grounds to supply the vast majority of their landings, which threatens the survival of already depleted populations by reducing their reproductive capacity and growth potential. Juvenile Shortfin Mako and Blue Sharks, in particular, are landed most frequently across the NMP. Available landings data also suggests that Blue Shark nursery grounds are more widely distributed along the coastline than shown in Figure 4.

Table 2: Species and size composition of artisanal landings samples from the NMP. While a variety of marine species were documented in these landings records, species shown are focal shark species in the MGEL literature review that have documented nursery grounds in the NMP.

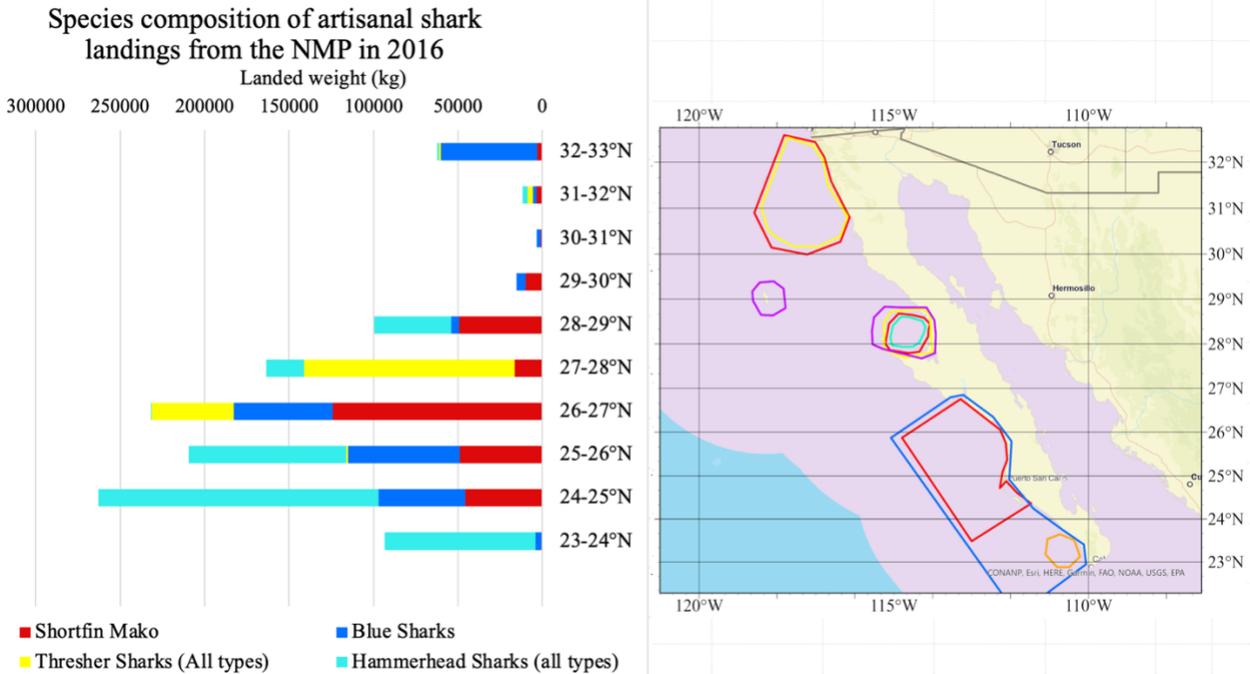| Species	Collective species and size composition of shark landings samples collected opportunistically by Santana-Morales et al. 2020 from Ensenada between 2007-2009.		Collective species and size composition of shark landings samples collected opportunistically by Cartamil et al. 2011 from Laguna Manuela between 2006-2008.		Collective species and size composition of shark landings samples collected opportunistically by Ramirez-Amaro et al. 2013 from the central coast of Baja California Sur between 2000-2010.	
	# of Measured Specimens	Juvenile Percentage	# of Measured Specimens	Juvenile Percentage	# of Measured Specimens	Juvenile Percentage
Shortfin Mako Shark Juvenile length: >200 cm	90	>95%	477	100%	181	100%
Blue Shark Juvenile length: >180-200 cm	1496	>95%	12	100%	93	>75%
Common Thresher Shark Juvenile length: > ~330 cm	43	100%	36	100%	36	100%
Great White Shark Juvenile length: >300 cm	No specimens recorded		12	100%	No specimens recorded	
Smooth Hammerhead Shark Juvenile length: >200-280 cm	No specimens recorded		224	100%	276	>95%
Silvertip Shark	No specimens recorded		No specimens recorded		No specimens recorded	
Bluntnose Sixgill Shark	No specimens recorded		No specimens recorded		No specimens recorded	

4.4 Fishing Interactions with Focal Shark Nursery Grounds: Government Records

Government landings records also suggest that artisanal fishing has an immense impact on focal shark nursery grounds. Importantly, this data contains many inaccuracies, as discussed above. While fishers are required to report total landings and their individual delivery camps, camp names are often referenced using local terminology, and many camps have indistinct spatial boundaries. However, research scientists at Duke University have worked to create an index of specific camp names and locations that are geo-referenced using satellite data (Nenadovic 2022). This index provides a focused estimation of where landings were caught, as pangas have an extremely limited range of only 35 km from their delivery location.

Figure 6 illustrates this georeferenced data from 2016, the most recent year for which site-specific data is available. Although specific landings volumes of 5 focal species were not available, these records contain landings volumes of Shortfin mako and Blue Sharks, as well as all types of Hammerhead and Thresher Sharks. Total landed volumes and species compositions were aggregated for all fishing camps within each degree of latitude to determine how focal shark catches vary along the NMP coastline.

As shown in Figure 6, fishers based in northwest Baja California near Ensenada landed approximately 60,000 kilograms (kg) of Blue Sharks in 2016, which were likely composed mostly of juveniles based on the scientific samples discussed above (Nenadovic 2022). Again, this suggests that Blue Sharks likely have a nursery ground in this area that is targeted by artisanal fishers. Moving southward, focal shark landings remain relatively low until approximately 29° latitude, near the northern end of Sebastian Vizcaino Bay. Total landing volumes increase drastically within the bay area across multiple species, including Shortfin Mako, Thresher Sharks, Hammerhead Sharks and Blue Sharks, which aligns with the species composition of proximal nursery grounds documented in the literature review. Most of this catch is likely composed of juveniles, suggesting that focal shark nursery grounds in Sebastian Vizcaino Bay are subject to especially concentrated fishing pressure.

Further south along the west coast of Baja California Sur, landings volumes remain extremely high, with Blue Sharks and Shortfin Mako composing approximately 100,000 kg of landed catch. Again, this result aligns with the literature review data, which suggests that both Shortfin Mako and Blue Sharks have a nursery ground in this area. Notably, Hammerhead sharks also compose a large portion of landed catch from this region, but species-specific data is not available to further delineate catch composition.

Figure 6: Landed weight and species composition of focal shark species from the NMP in 2016. Each bar represents total landings reported by all geo-referenced fishing camps within 1 degree of latitude along the western coast of the NMP.

5. Existing Regulatory Framework

5.1 Regulatory Authority of CONAPESCA and Promulgated Legislation

Shark fishing in Mexico is regulated primarily by the Federal Commission on Fisheries and Aquaculture (CONAPESCA), which exerts control over the entire NMP region. CONAPESCA is a branch of the Secretariat of Agriculture (SAGARPA), the federal ministry that oversees all national food resources in Mexico (OECD 2006). Broad management goals for the NMP shark fishery are defined through the Mexican National Plan of Action for the Management and Conservation of Sharks, Rays and Related Species (MNPOA), which was instituted in 2004 by CONAPESCA (Saldana-Ruiz et al. 2019). This document mandates that local shark population should be exploited sustainably via "protection" of critical habitat areas and endangered species.

To further this underlying management goal, CONAPESCA instituted a measure called NOM-29 in 2007, which provides the central rules governing the NMP shark fishery through the present (Sosa-Nishizaki et al. 2020a). Firstly, NOM-29 requires that all registered shark fisheries complete daily logbook entries of caught species and volumes, providing the basis of the government landings records referred to above (DOF 2007). Secondly, this regulation categorically prohibits retention of three endangered species in the NMP: Whale Sharks, Great White Sharks, and Basking Sharks, while all other shark species and sizes can be retained. NOM-29 also restricts the total number of shark fishing permits issued to artisanal fishers and

prohibits the use of gillnets throughout the year in the NMP. Finally, NOM-29 requires that less than 350 hooks are used on each longline set and closes the entire NMP shark fishery between May 1st-July 31st to reduce fisheries interactions during their primary spawning period.

5.2 Regulatory Authority of SEMARNAT and Promulgated Legislation

In addition to CONAPESCA, the Mexican Government's Secretariat of Environment and Natural Resources (SEMARNAT) may also regulate NMP shark fisheries through the creation of Natural Protected Areas (NPAs) (OECD 2006). Over the past 20 years, SEMARNAT has endeavored to improve protections of domestic natural resources by designating NPAs in vibrant terrestrial and marine ecosystems, which may include a variety of limitations on human activity within their boundaries. Yet, while SEMARNAT has designated three marine NPAs in the waters off Baja California and Baja California Sur, current regulations in these areas generally have a minimal impact on shark fishing efforts (Saldana-Ruiz et al. 2019).

The only NPA located along the coastline of the NMP is known as the Pacific Islands of Baja California Biosphere reserve, which SEMARNAT established in 2016. This reserve covers 21 different islands along the NMP coast, which are defined as "core areas," and surrounding waters, which are defined as "buffer areas" (Graham 2017). However, this reserve was designed primarily to protect terrestrial species like seabirds on the islands themselves instead of marine species in proximal waters (Garcia-Rodriguez and Sosa Noshizaki 2018). In Sebastian Vizcaino Bay, for instance, the core area of the reserve encompasses the Benitos Islands, Cedros Island and Navidad Island, while the bay itself is defined as a buffer zone. As shown in Figure 7, most of the bay is technically within the reserve, covering a documented nursery ground for Shortfin Mako, Thresher Sharks, Smooth Hammerhead Sharks and White Sharks. Nonetheless, shark fishing regulations in the bay are highly limited; assuming compliance with NOM-29, SEMARNAT still permits artisanal shark fishing in buffer zone areas (Garcia-Rodriguez and Sosa-Nishizaki 2018).

Figure 7: Location of the Islas Del Pacifico Peninsula de Baja California Biosphere reserve in Sebastian Vizcaino Bay and proximal fishing activities from Garcia-Rodriguez and Sosa-Nishizaki 2018. The grey outline defines the reserve area while grey shaded regions represent areas with concentrated shark fishing activity. Blue shading represents Great White Shark nursery grounds that are documented by Garcia-Rodriguez and Sosa-Nishizaki 2018.

SEMARNAT has also designated two NPAs further from the NMP coast, which provide more substantial protections for focal shark nursery grounds. Firstly, SEMARNAT created an NPA around the Revillagigedo Islands in 1994, which includes the islands themselves and a buffer zone stretching six miles from the coast. As shown in Figure 4, this buffer zone includes a documented nursery ground for Silvertip Sharks, which is protected from fishing within the reserve boundaries (Le Croizier et al. 2020). Yet while the reserve itself encompasses 57,000 square miles, the protected marine area only composes 40 square miles or .07% of the NPA (Saldana-Ruiz 2019). Juvenile Silvertip aggregations that extend beyond the small buffer zone area remain unprotected through existing legislation.

Secondly, SEMARNAT designated an NPA around Guadalupe Island in 2005, which focuses more explicitly on protecting marine species. In contrast to the other reserves, this NPA primarily encompasses marine areas; only 102 square miles of the 1,840 square mile reserve area is composed of land (Aguirre-Munoz et al. 2013). As shown in Figure 4, this reserve includes a known nursery ground for White Sharks, which is protected from fishing under reserve regulations and NOM-29.

Despite these local protection measures, existing NPAs generally fail to provide comprehensive protections for focal shark nursery grounds, especially along the coast of the NMP where artisanal fishing efforts are concentrated. Recognizing this problem, SEMARNAT created a new initiative in 2018 known as the Action Program for the Conservation of Sharks and Ray Species (APCSRS), which was designed to incorporate these species into reserve protections (Sosa-Nishizaki et al. 2020a). Protecting shark nursery grounds, in particular, was defined as a primary objective of the new initiative. However, this program has not yet been implemented.

6. Future Strategies for Regulating Fishing Activities in Focal Shark Nursery Grounds

6.1 Regulatory Options: Potential Benefits and Shortcomings

Existing research on small-scale fisheries suggests that community-based conservation efforts are more likely to yield concrete conservation benefits than top-down strategies, where centralized regulatory bodies implement new fishing restrictions with minimal fisher participation or input. Top-down strategies are often ineffectual because ensuring compliance with new regulations is extremely difficult, a clear problem in the NMP. The predominance of illegal fishing and sheer number of vessels and ports involved in the fishery make comprehensive enforcement efforts expensive and impractical. If fishers themselves do not believe in the underlying goals or legitimacy of a given regulation, they can easily disregard it (Quintana and Basurto 2020).

Community-based conservation measures avoid this problem by allowing fishers themselves to develop conservation strategies that they are personally invested in adhering to (Quintana and Basurto 2020). Additionally, small-scale fishers are often highly cognizant of local fish population dynamics, as well as how fishing efforts contribute to their own well-being and the well-being of the communities in which they are based (Nightingale 2013; Smith and Clay 2010; Leslie et al. 2015). While these factors are often overlooked by centralized management bodies, the community-based framework provides a means of directly incorporating this invaluable knowledge into new conservation initiatives.

Despite these shortcomings, the importance of centralized management bodies should not be categorically discounted in shark conservation efforts. Authorities like CONAPESCA can analyze larger areas wholistically to identify more localized conservation priorities. For instance, the conservation importance of Sebastian Vizcaino Bay is defined partially through its relatively high level of shark species diversity compared to the rest of the NMP region. These larger-scale distinctions may not be apparent to fishers who only travel within 35 km of their home port. Similarly, local fishers may be unaware of larger-scale population patterns, such as the precipitous decline in Shortfin Mako populations in the northern Pacific. Because these critical conservation concerns may not be immediately obvious to local fishers, they may not be adequately considered in community-based management decisions. Conversely, regulations that are primarily developed and implemented by centralized regulatory bodies like CONAPESCA, which aggregate and compile data across multiple regional districts, can incorporate these larger-scale concerns into local fishing practices and efforts.

Three broad regulatory strategies can be implemented by centralized management bodies to limit juvenile landings of marine species, all of which could help protect focal shark nursery grounds in the NMP. The first is "input controls," which involve restrictions on when, how and/or how many fishers can fish (Russell et al. 2012). Recent regulatory efforts by CONAPESCA have primarily utilized this strategy, through the seasonal shark fishing ban, prohibition of gillnets and limit on total number of longline hooks (DOF 2007). Additional gear restrictions instituted by CONAPESCA, such as further reducing the number of hooks used in longline sets, could help reduce total catch volumes, indirectly reducing juvenile shark landings (Russell et al. 2012). However, these measures may unnecessarily reduce food availability for artisanal fishers without comprehensively protecting shark nursery grounds. Given that fisheries observers currently only cover 5% of artisanal vessels per year, verifying widespread compliance with new gear restrictions would also be extremely difficult (Saldana-Ruiz 2019).

A second option is "output controls," which involve restrictions on which species are retained, total allowable catch volumes and/or length requirements for retained sharks (Russell et al. 2012). Unlike input controls, new length requirements would provide a more focused and comprehensive means of protecting shark nursery grounds by reducing or eliminating juvenile retention of specific shark species. However, new length requirements instituted by CONAPESCA may also be very difficult to enforce. Given that catches are not offloaded at centralized locations, regulators would need to monitor the multitude of small fishing camps to ensure compliance. The inaccessibility of these coastal areas and large number of camps would make this effort impractical. Many fishers also retain their catch as a personal food source, limiting opportunities for enforcement personnel to survey catches from land.

A third option involves closing specific areas of the NMP to shark fishing, either within a specified time period or throughout the year. SEMARNAT could place these closed areas around documented focal shark nursery grounds, preventing fishers from targeting juvenile aggregations. The high degree of overlap across multiple focal shark species in the NMP may make small-scale closures especially effective because artisanal fishers catch a variety of shark species opportunistically (Cartamil et al. 2011). A single, small-scale closure that encompasses a highly diverse nursery ground could drastically reduce fishing threats for all of the shark species within it, instead of only protecting a single species that fishers are targeting. From an enforcement perspective, this option is also well-suited to the artisanal fleet because regulators are not required to monitor the vast array of boats and/or ports involved in the fishery; instead,

they must simply monitor the closed area itself to ensure compliance, which would require far less manpower and resources.

6.2 Recommendations

Given the advantages and shortcomings of each regulatory strategy, area closures provide the most practical, effective strategy through which the Mexican Government can protect nursery grounds in the NMP. To utilize available resources most efficiently, these closures should encompass areas with juvenile aggregations for multiple threatened shark species that are subject to concentrated fishing pressure. All three of the following regions meet these criteria:

A) Waters along the northwest coast of Baja California
This area contains nursery grounds for Endangered Shortfin Mako, Common Thresher Sharks and Blue Sharks, all of which are subject to concentrated fishing effort from nearby ports such as Ensenada (Kot et al. 2022; Santana-Morales et al. 2020; Nenadovic 2022).

B) Sebastian Vizcaino Bay
This area contains nursery grounds for Endangered Shortfin Mako, Common Thresher Shark, Great White Shark, Smooth Hammerhead Sharks and Blue Sharks, all of which are subject to concentrated fishing effort from nearby ports such as Laguna Manuela and Bahia Tortugas (Kot et al. 2022; Cartamil et al. 2011; Garcia-Rodriguez and Sosa-Nishizaki 2018; Onate-Gonzalez et al. 2017; Nenadovic 2022).

C) Waters along the central coast of Baja California Sur
This area contains nursery grounds for Endangered Shortfin Mako, Blue Sharks, Common Thresher Sharks and Smooth Hammerhead Shark, all of which are subject to concentrated fishing effort from nearby ports such as San Carlos (Kot et al. 2022; Ramirez-Amaro et al. 2013; Nenadovic 2022).

While prohibiting shark fishing within all three regions would facilitate growth of multiple threatened shark populations, these areas collectively compose the majority of productive artisanal fishing grounds in the NMP. Closing these vast areas indefinitely would threaten the health of many artisanal fishers and their families, who depend on these fishing grounds as a critical food source (Sosa-Nishizaki et al. 2020a). CONAPESCA would also need a multitude of vessels to comprehensively patrol these regions, an expensive and impractical proposition. Thus, implementing small-scale area closures within these regions will be more feasible and socially responsible.

Recommendation 1: SEMARNAT should institute a year-round shark fishing ban in the NPA buffer zone that covers Sebastian Vizcaino Bay.

Nursery grounds in Sebastian Vizcaino Bay contains the most diversity of focal shark species within the smallest overall area in the NMP, including Endangered Shortfin Mako (Rigby et al. 2019). Additionally, artisanal fishers in this area report extremely high landing volumes of focal shark species, suggesting their nursery grounds are subject to concentrated fishing effort (Nenadovic 2022). Thus, prohibiting shark fishing within the NPA buffer zone that covers Sebastian Vizcaino Bay will significantly reduce juvenile losses of a multitude of threatened

shark species, while still allowing proximal fishers to reach accessible fishing grounds in surrounding waters. In the immediate future, this closure may reduce total shark landings for local fishers, but it will ultimately facilitate growth of threatened shark populations, potentially increasing adult landings outside the closed area.

Through APCSRS, SEMARNAT has also recognized that incorporating shark nursery protection measures into existing NPAs represents an important conservation initiative (Sosa-Nishizaki et al. 2020a). This new measure would further the goals of APCSRS by providing concrete protections within an area of documented conservation importance.

7. Future Strategies for Increasing Data Availability and Research Efforts

7.1 Current Data Gaps and Research Challenges

To ensure the continued sustainability of the NMP shark fishery, the Mexican government should enact additional small-scale area closures within the three regions defined above, which can be implemented by SEMARNAT using the existing NPA framework. Through the APCSRS program, these new marine NPAs will protect highly diverse, vibrant shark ecosystems throughout the NMP in addition to the wide array of terrestrial species that are already protected.

Determining the optimal placement of closed areas is dependent on concerted research efforts, which are necessary to delineate the spatial extent of shark nursery grounds as well as the species composition, residence times and abundance patterns of juvenile sharks within them (Heupel 2007). All of these factors are critical to determining how specific areas contribute to the growth and resilience of threatened shark populations and how proximal fishing activities affect underlying population stability. Existing research on all of these factors in the NMP is highly limited, so new research efforts will be necessary to determine where additional closed areas should be placed.

A primary research objective should be developing more comprehensive, finer-scale representations of where specific shark nursery grounds are located within the NMP and how artisanal fishing affects them. Scientific studies that either observe artisanal landings or recover juvenile specimens directly could further this initiative by providing accurate, verifiable data. However, the scope of these studies is inherently limited. Given the vast array of vessels and ports involved in the fishery, scientists can only collect landings samples from a small number of boats or ports in specific regions, preventing researchers from collecting comprehensive, current data across the entire NMP for multiple shark species.

Comprehensively identifying shark nursery grounds in the NMP through direct specimen recovery would also be impractical. As outlined above, nursery grounds are defined as areas where juvenile sharks aggregate repeatedly after each spawning cycle. (Heupel 2007). Simply identifying a small number of juvenile specimens in a given location has minimal utility for government regulators because the long-term efficacy of an area closure is contingent upon juveniles repeatedly aggregating within it over multiple years. To prove repeated aggregation in a single location, scientists would need to collect a multitude of juvenile samples over multiple spawning cycles. Implementing this strategy throughout the NMP would be exorbitantly expensive, and direct recovery provides no indication proximal fishing threats.

In contrast, more detailed logbook reports could be used to generate an expansive dataset with minimal resource expenditure. Artisanal fishers can provide comprehensive data across the

NMP due to the vast array of participating vessels, their indiscriminate landing of multiple shark species and their consistent operation during the majority of the year. Because individual vessels are based in a multitude of camps along the coast and have a range of only 35 km, their reports will also cover the majority of accessible fishing grounds. Compelling fishers to record more specific, accurate landings data may also be more cost-effective for the Mexican Government than employing a multitude of qualified scientists to study the entire NMP region.

Another primary research objective should be developing a more detailed understanding of social impacts that may result from new area closures. However, existing research on how artisanal shark fishing in the NMP contributes to the welfare, wellbeing and livelihoods of local community members remains sparse (Sosa-Nishizaki et al. 2020a). Input from local fishers will provide valuable insights regarding local shark population dynamics and potential social impacts related to new regulations, so the Mexican government should directly involve them in the policy-making process.

7.2 Recommendations

Recommendation 1*:* CONAPESCA should convene stakeholder meetings within artisanal fishing communities to solicit local input regarding the potential ecological and social impacts of new area closures.

These meetings will provide a vast wealth of socio-ecological knowledge, which will help maximize the conservation benefits of new regulations while minimizing adverse social impacts. Facilitating local participation will also increase the legitimacy of new regulations to artisanal fishing communities, potentially increasing compliance rates.

Recommendation 2: CONAPESCA should fund research efforts that seek to understand how NMP shark landings may contribute to the illegal shark fin trade.

While existing research suggests that shark landings are primarily utilized as a food source in the NMP, shark fins remain highly valuable in illegal markets. Selling shark fins to illegal exporters may represent an attractive source of supplementary income for local fishers. However, the extent to which artisanal shark fishers in the NMP contribute to these illegal exports remains difficult to quantify accurately given the clandestine nature of these transactions. Concerted research efforts are necessary to expose illegal fin sales and develop new enforcement strategies to prevent them.

Recommendation 3: CONAPESCA should require that fishers record the specific species and sizes of each landed shark.

When combined with corresponding delivery port locations, this data will help researchers determine the spatial boundaries of shark nursery grounds for specific species while simultaneously quantifying fishing threats in these areas. Although fishers themselves may be unable to distinguish different species, government officials can institute an educational campaign to help fishers identify physical differences between similar-looking specimens (Sosa-Nishizaki et al. 2020a).

These new requirements will require additional effort from fishers themselves, which may be inconvenient and unpopular. However, the limited capacity of individual vessels and the vast number of participating fishers allows this effort to be distributed widely across the fishing fleet. Given that panga vessels are only 5-8 meters long, a single vessel is only capable of

retaining a small quantity of sharks per trip. Thus, individual fishers can efficiently record the size and species composition of their own landings.

Recommendation 4: Once SEMARNAT implements new marine NPAs, they should fund observational research efforts that study protected juvenile shark aggregations with them.

While area closures have been implemented in a variety of marine ecosystems, the success of these measures has varied. Area closures can increase fishing pressures in surrounding waters, preventing growing populations within the closed area from contributing to populations outside of it (Sanchirico et al. 2002). Thus, continuing to monitor the species composition and abundance levels of juvenile sharks in and around closed areas will be necessary to assess their effect on underlying populations. Importantly, once an area closure is implemented, logbook records will no longer provide data within it, so scientific research efforts will be necessary to monitor protected juvenile aggregations over subsequent years.

Scientific studies that research Great White Shark nursery grounds may also be especially useful to CONAPESCA if new logbook requirements are implemented. Unlike the other focal shark species, Great Whites are now protected throughout the NMP under NOM-29 (DOF 2007). As a result, catch records will not provide data for this species, so scientific research is necessary to delineate the spatial distribution of their NMP nursery grounds more accurately. Studies that directly sample artisanal landings can also determine where juveniles White Sharks are still caught either as bycatch or through illegal targeting.

Recommendation 5: CONAPESCA should fund research efforts that study how industrial fishing fleets operating further from shore impact shark nursery grounds in the NMP.

Although artisanal panga vessels clearly have an immense impact on threatened shark nursery grounds in the NMP, these vessels only operate within 35 km of land. The MGEL literature review suggests that shark nursery grounds extent much farther from the coast, likely overlapping with productive fishing grounds for larger vessels. For instance, 32 Mexican longline vessels greater than 10 meters in length are currently registered to catch sharks off the west coast of Baja California, which may contribute to juvenile losses through bycatch loss or direct targeting (Sosa-Nishizaki et al. 2020). If nursery grounds extend beyond the 200-mile limit of Mexico's EEZ, foreign vessels may contribute to juvenile shark losses as well. Quantifying and reducing these landings will help maximize the conservation benefits of area closures closer to shore.

Critically, these larger vessels utilize vessel monitoring systems, which can be used to map the spatial distribution of fishing effort. Recent monitoring programs like Global Fishing Watch have used satellite tracking data to develop accurate, finer-scale representations of when and where larger vessels are fishing (Global Fishing Watch 2022). In conjunction with logbook records, this data can help scientists identify shark nursery grounds that are impacted by industrial fleets.

8. Conclusion

Given the depleted state of global shark populations and high risk of extinction across multiple shark species in the Pacific Ocean, protecting their nursery grounds in the NMP represents a critical conservation concern. However, comprehensive, accurate data, which is necessary to inform regulatory efforts, remain highly limited. The dynamics of proximal

fisheries, both legal and illegal, also make enforcing new regulations extremely difficult. Addressing both of these problems will require personnel and resources, which may not be available to government bodies like CONAPESCA and SEMARNAT. Thus, assistance from NGOs like PEW and local community members will be critical to establishing more effective protection measures for these areas.

   Synthesis of existing and emerging research can be used to focus collaborative efforts between the Mexican government, local community members and NGOs. In the NMP, utilizing logbook records to inform the placement of new marine NPAs provides a realistic and cost-effective means of drastically reducing fishing threats in focal shark nursery grounds. Despite these advantages, the utility of logbook data is contingent upon its accuracy. NGOs like PEW can assist the Mexican government in efforts to educate local fishers on species distinctions and efficient recording strategies to maximize the accuracy of logbook data while minimizing fisher effort. Convening stakeholder meetings in local fishing camps along the NMP can also facilitate fisher participation in the management process, which will inform new regulatory strategies while simultaneously increasing their legitimacy to coastal fishing communities. Finally, PEW can help fund scientific research within newly formed marine NPAs and further offshore to ensure that they contribute to the resilience and growth of underlying shark populations. Together, these measures effectively address the regulatory and enforcement challenges of protecting threatened shark nursery grounds the NMP.

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