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2023 NSARB 2023-001

Nova Scotia Aquaculture Review Board

Between:

KELLY COVE SALMON LTD.

APPLICANT

- and -

MINISTER OF NOVA SCOTIA DEPARTMENT OF FISHERIES AND AQUACULTURE

PARTY

- and -

KWILMU'KW MAW-KLUSUAQN NEGOTIATION OFFICE, QUEENS RECREATIONAL BOATING ASSOCIATION, 23 FISHERMEN OF LIVERPOOL BAY, REGION OF QUEENS MUNICIPALITY, and PROTECT LIVERPOOL BAY ASSOCIATION.

INTERVENORS

Affidavit of Neil Hammerschlag
Sworn on January 19, 2024

I, Neil Hammerschlag, of Boutiliers Point, in the Province of Nova Scotia affirm as follows:

1. I have personal knowledge of the evidence affirmed in this Affidavit except where otherwise stated to be based on information and belief.

2. I state, in this Affidavit, the source of any information that is not based on my own personal knowledge, and I state my belief of the source.

3. I have been asked to review and provide expert opinion regarding the impacts of the proposed Kelly Cove Salmon Ltd. aquaculture boundary amendment and lease application for locations in Liverpool Bay, Queen's County enumerated as AQ#1205x, AQ#1432, AQ#1433 (the "Application"), on sharks including the endangered white shark (Carcharodon carcharias) and shark behaviour.

4. I have authored a report detailing my analysis and conclusions regarding the impacts of the proposal set out in the Application, on Liverpool Bay ("the Report"), attached hereto as **Exhibit "A"**.

5. My qualifications as a subject matter expert on the impact of the Application on sharks including endangered white sharks and their behaviour, are set out in my Curriculum Vitae attached hereto as **Exhibit "B"**.

6. Based on my education and experience, my areas of expertise include marine biology, ecology, and conservation, with a specialization in shark movement ecology, behavioral ecology, and conservation biology. This expertise includes the study of white sharks for over 20 years.

7. The Report attached to this affidavit as Exhibit "A" represents my professional opinion with respect to the impacts of the proposed aquaculture operation as set out in the Application, on endangered white sharks in Liverpool Bay.

AFFIRMED before me at Boutilier's Point Nova Scotia, this 19 day of January 2024, using real-time, audio-visual technology:

[redacted]

Barrister of the Province of Nova Scotia

[redacted]

Neil Hammerschlag

NATASHA PUKA
A Barrister of the Supreme
Court of Nova Scotia

2023 NSUARB 2023-001

This is Exhibit "A" referred to in the Affidavit of Neil Hammerschlag sworn to before me this 19 day of January 2024

[redacted]

Barrister of the Province of Nova Scotia

NATASHA PUKA
A Barrister of the Supreme
Court of Nova Scotia

REPORT by Dr. Neil Hammerschlag on the Potential Threats of the Proposed Salmon Farming on White Sharks, a Species At Risk.

Overview

The information below describes an assessment to risk to white sharks (*Carcharodon carcharias*) of the proposed salmon farm intended for the Liverpool Bay area by Kelly Cove Salmon LTD. (KCS). This assessment is based on five topical areas: (1) previous information found in the published scientific literature, (2) the presence of white sharks in the Liverpool Bay area, (3) the mechanism by which the proposed salmon farm could attract white sharks to the cages (4) the proposed mitigation measures in place to reduce risk to white sharks, and (5) notes on the potential of the netting to withstand the bite of a white shark. These five areas are discussed below, with a summary to follow.

1. Marine Aquaculture and Sharks

A review of scientific literature provided evidence and scientific opinion that ocean-based fish aquaculture farms can attract sharks and pose threats to sharks. These threats include attraction, entanglement, and entrapment, which could result in alternations of natural behavior, injury, or death (Scholl and Pade 2005). For example, sharks can be attracted to the smells and sounds from shark cage operations, which includes being attracted to wild fishes that aggregate around farms as well as through multiple stimuli associated with the fish farming itself, including the presence and activity of live fish in the cages, the presence of dead fish at the bottom of the cages, the odour trail generated during feeding, farming operation sounds, and the physical structures (Scholl and Pade 2005, Bath et al. 2022). Shark attraction to fish farms has been documented globally, including in Puerto Rico, Hawaii, the Bahamas, Canary Islands, Latin America, the US Pacific Northwest New Zealand, and Australia (Bath et al. 2022). Several studies have noted that through aggregation, fish farms may alter the natural behavior of sharks (e.g. Papastamtiou et al. 2010). As a result of being attracted to and aggregating at the cages, sharks may spend less time elsewhere as they would normally do (Scholl and Pade 2005). Once at the cages, sharks may also try to enter the cages to feed on the farmed fish. As a result, white sharks have been found to tear holes in the netting, and even break through the bottom and sides of the cage netting (e.g., Galaz and De Maddalena; Figure 1). In South Australia, aquaculture cages have been identified as an entanglement threat to white sharks (Taylor et al. 2016, Bath et al. 2022). Since white sharks are obligate ram ventilators (Martin 2003), which means they need to keep swimming to breathe, if they become entangled in the netting, they will be immobilized and shortly die from suffocation. If a white shark bites through the cage, or breaks into the cage and becomes entrapped, then trying to remove the white shark from the cage becomes an issue, especially from a human safety perspective given the size and strength of a white shark, not to mention it would likely be in a stressed state from entrapment (Scholl and Pade 2005). As a result, in past circumstances, white sharks that have become entrapped in fish farms have been killed to remove them (Cheshire 2006). Even the use of heavier/stronger predator nets around cages, with the intended purpose of repelling sharks from the inner fish cages, can pose a threat to white sharks as these large-mesh nets have previously been found to trap and kill white sharks (Cheshire 2006). While removing the predator nets have reduced white shark entanglement

mortalities, it has become easier for white sharks to bite through the thinner/weaker inner cage netting (Cheshire 2006). As noted before, unfortunately these white sharks have been destroyed to prevent them from eating the farmed fish and to allow divers to enter the water and repair the net (Cheshire 2006). Indeed, an estimated 20 white sharks are killed every year at marine aquaculture farms within Australia (Cheshire 2006).

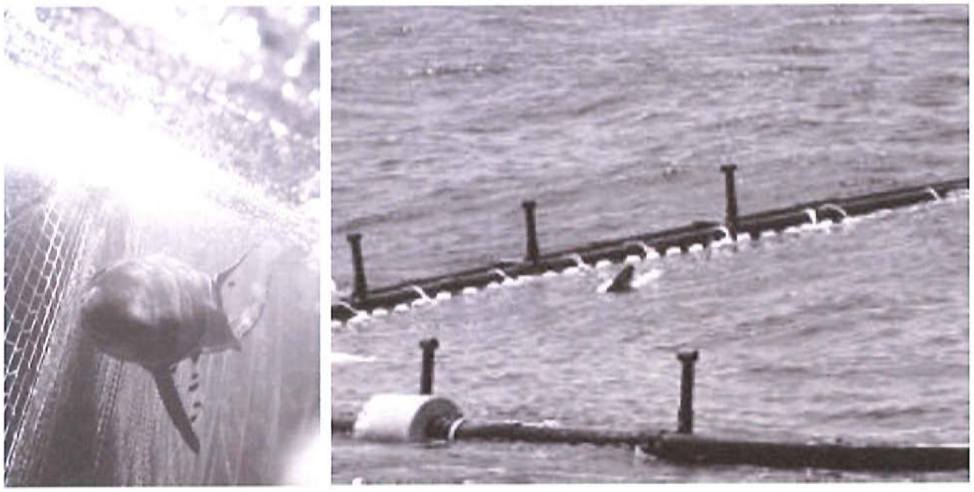

Figure 1. *A white shark trapped in a tuna farming cage of Libya. Source: Galaz and De Maddalena (2004)*

2. Presence of White Sharks in Liverpool Bay

The potential for white sharks to interact with the salmon farms depends on whether white sharks are found in the area of the proposed cages and if the environmental conditions near the cages are optimal for white sharks to inhabit, which is indeed the case based on the following available information:

- Liverpool Bay and surrounding nearshore area occurs within the high use areas of white sharks in Atlantic Canada during their summer and fall foraging period (Bastien et al. 2022, Bowlby et al. 2022, Franks et al. 2022, Figure 2)
- Water temperatures at the current and proposed aquiculture sites as described by KCS overlap with optimal temperature preferences of white sharks in Atlantic Canada (12-19°C; Figure 3).
- Previous tracking of white sharks has indicated presence in Liverpool Bay (DFO 2022). For example, tracking data from over a three-

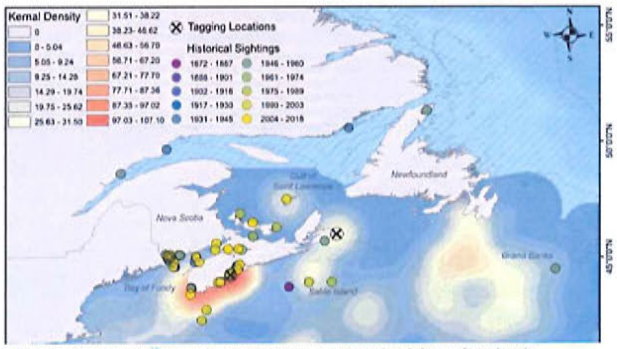

Figure 2: *Distribution and hotspots of white sharks in Atlantic Canada waters derived from sightings and telemetry data. Heat maps are kernel density estimates. Source: Bastien et al. (2020).*

month period (August–October 2019) detected the presence of at least 15 individual tagged white sharks in Liverpool Bay around the proposed aquaculture sites (DFO 2022). This figure likely underestimates the number of white sharks present in the area as it only accounts for the number of tagged individuals. For example, working off the area of Queens County, our team observed 35 different white sharks over just a two-month period (September and October of 2023).

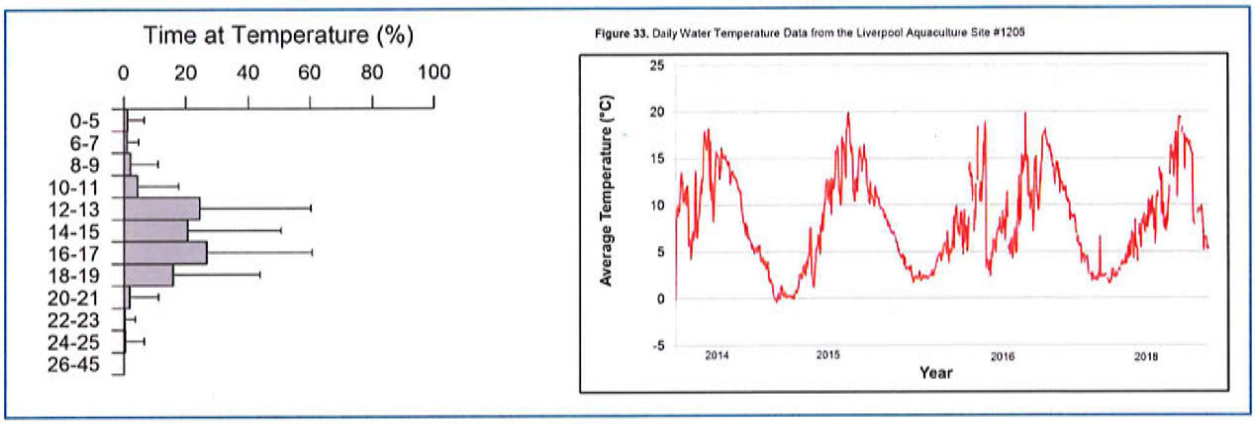

Figure 3. *Left = Percent time at temperatures (C) of white sharks in Atlantic Canada from satellite tags (Source: Bowlby et al. 2002). Right = average temperature data from Liverpool salmon far site (Source: Application 1, Exhibit 5)*

3. Salmon Aquaculture and White Shark Attraction

Sharks have an excellent sense of smell and rely heavily on their sense of smell to locate prey. Studies have shown that sharks can detect smells even in extremely low concentrations (Abel and Grubbs 2020). In fact, sharks have been referred to as "swimming noses." Eighteen percent of a white shark's total brain mass is made up of their smelling organ (Demski and Northcutt 1996), meaning that a huge proportion of their brain is dedicated to smell alone. Sharks are attracted to biomolecules (amino acids and nucleotides) found in fish tissues, fish pee, and in the mucus covering the skin of the fish (Klimley 2013). These smells emanate from the fish and create an odour trail that sharks can follow to its source (Abel and Grubbs 2020). Sharks are also highly attracted to the smell of chemicals that are produced during tissue decomposition in fish (Betaine, trimethylamine, trimethylamine oxide; Klimley et al. 2013), so dead fish will produce a strong odor trail attractive to sharks. Studies have shown that extracts from oily-fleshed fish elicit more interest in sharks than extracts from dryer flesh fish (Abel and Grubb 2020), salmon is a very oily fish. Sharks also have a great sense of hearing in lower frequencies (<1000 Hz), especially low-frequency pulses that are produced from struggling fish (Abel and Grubbs 2020, Klimley et al. 2013). Since lower frequency sounds travel far in water (hundreds of kilometres from the source), sharks can be stimulated from sounds at a distance. Given the sensitivity and attraction of sharks to odors and sounds produced by fish, there are several primary ways by which white sharks would be attracted to the salmon pens:

1. During stocking of 660,000 salmon per pen (nearly 2,000,000 total) in a relatively localized area, there would be an abrupt change in smell and noise that would be attractive to white sharks.

2. Post stocking, chances of post transfer mortality are increased (App 1, Exhibit 5; Table 9, page 128). Such mortality would result in decaying salmon that would release chemicals attractive to white sharks.
3. During grow out in a localized spot, farmed salmon would continuously release smells, through their pee, by mucus sloughing off their skin, shedding of DNA, and release of chemicals at their gills. Also, salmon mortalities are expected during grow out, which would result in decaying fish.
4. During harvesting, salmon are likely being herded, captured, and physically removed in some way, which will likely increase salmon stress levels, increasing the sounds of struggling fish emanating from the cages. This harvesting could also result in injuries to the salmon and leaking blood, oils, and other organic tissues from the fish.
5. Fish feed itself is likely made of fish, which are likewise attractive to sharks, both when chemicals are released as fish consume, but also any leftover or uncontained pellets that leak out of the pens.
6. White sharks can also become attracted to other prey that are associated with the cages. It is well documented that subsurface structures serve as an attractant to wild fishes that would be attractive to white sharks. Beyond these wild fishes, the cages will likely lure in seals that are prey of white sharks in Atlantic Canada (Franks et al. 2022). Smells and sounds of the seals would also be attractive to the white sharks.

- I do not see any mitigation strategy or control mechanism listed in Table 7 of Application 1 (Exhibit 5) or elsewhere that would limit the attraction of white sharks to the above smell and sound stimuli associated with the salmon farms.
- The only relevant strategy identified that would serve to help prevent the attraction of white sharks to the cages in some way relates to "*disposal of mortalities*" which refers to blood water and offal from mortalities. Here, the method to control this hazard is described as "*Controlled with waste management strategy, including blood water and offal; approved by NSDFA.*" Section 7.2.3.2 (Containment Strategy) seeks to describe the primary containment strategy with respect to mortality collection. It states "*Divers collect the mortalities, which are placed in lined, leak-proof, covered tubs for transport to shore. Once brought to shore, all mortalities are taken to Queens County Landfill via Whynot Trucking. The procedure considers containment risks. Note, the mortality collection schedule varies depending upon the age of the fish. During smolt entry and the first few weeks post entry, the frequency of mortality collection may increase. After these production milestones, mortality collection occurs once per week unless there is an identified fish health event. The approved procedure to collect mortalities will also be applied to the operations of the proposed Mersey Point and Brooklyn aquaculture sites.*" It is clear that leak-proof tubs will prevent the release of smells from the dead and/or decaying fish during removal from the cage, but it doesn't prevent the release of such smells from dying or dead fish during the period between cage checks, which can be up to a week. Given 1,980,000 salmon at any given time, there is a high potential for

mortality. Even a mortality of only 1% or 5% would result in 19,800 and 99,000 dying/dead fish decaying in the cage for 1 week.

4. Mitigating Threats to White Sharks

- Section 5.3.1 of Application 1, Exhibit 5 (*Critical Habitat and Mitigation Plans for Wildlife*) describes strategies for controlling impacts to critical habitat and wildlife. The section states that "KCS operates with a Wildlife Interaction Plan (WIP) that outlines all control measures and special requirements as they relate to wildlife encounters at the site (Appendix E)."
    - The only control measure described for sharks in section 5.3, reads "*KCS personnel will not attempt to attract, capture or harass any sharks in any way.*" (Section 5.3.1). Unfortunately, this fails to address issues of sharks being attracted to the pens via the smell and sound stimuli as noted in #3 above.
    - Section 5.4 of Application 1, Exhibit 5 (*Impacts to Other Users Including Wildlife*) describes interactions with predators and predator deterrent system to be employed, noting "*Predator deterrence is a key to containment management. Predator exclusion using netting include predator netting, bird nets, shark guards, and containment nets.*" While "shark guards" are briefly noted, there is no further mention or description throughout the either the applications or Wildlife Interaction Plan. Thus, it is not clear what the shark guards are, how they work, how they are maintained, when they are deployed or not, and whether these guards could injure white sharks.
    - Section 5.4.1 further states that "*Predator/seal nets surrounding the sea cage enclosure nets will be present during the months of December to May to aid with predator deterrence. Predator nets will not be placed on the cages from May to December as this has historically been shown as a low time for predators to be found in and around the site. Removal of the predator nets on the cages during these months will aid in reducing the amount of biofouling on the cages.*" For white sharks, this is problematic as the primary period of white shark occurrence in the region is June through December, peaking from July through October (Bastien et al. 2020, Figure 4b). This is precisely the period during which the predator exclusion nets are not present. This makes entanglement, capture, and breach of the cage by white sharks more likely.
- Section 5.4.1 states "*The Wildlife Interaction Plan (WIP) contains prevention and control measures for wildlife (Appendix E).*" Upon inspection of the WIP, section 6 of describes the specific control measures for wildlife interactions.
    - The opening of section 6 states "*Any measures taken to protect fish from predators are always carried out in a manner that considers predator welfare and does not endanger the predator population; however, if a predator cannot be deterred and is threatening human safety or the security of the containment, it may be dispatched with Saltwater Management consent AND in accordance with Provincial, State or Federal Regulations.*" However, there is no description of how the predator will be "*dispatched.*" This is important given the likelihood of

sharks being attracted to the cages, which would represent a threat to human safety and the security of the containment if a pen breach would occur.

- Section 6.1 (*Passive Control Measures*) list that the "*primary containment net will be protected from predators using a predator net as needed*". However, as noted above, the predator nets will not be in place when white sharks are present in Atlantic Canada.
- Section 6.2 (*Active Control Measures*) list the use of acoustic deterrent devices (ADDs) deployed under the cages to deter marine mammals; however, there is no mention of sharks. Details on the frequency and strength of sounds being produced by the ADDs are not provided. However, if ADDs are producing high frequency sounds, they are likely outside of the detectable hearing range of sharks. If ADDs are producing low frequency sounds, these are detectable by sharks and may actually work to attract sharks as research has shown that sharks are attracted to low frequency sounds as they mimic those produced by struggling fish. Thus, ADDS will not work serve as a deterrent to white sharks, possibly even serving as an attractant. That being said, the Report on Consultation suggests that ADDs may not even be used.
- Section 6.3 (*Lethal Control Measures*) states that lethal control measures are prohibited unless permitted. It is unclear if KSC will have a permit to kill white sharks. However, given the potential danger to divers of trying to release a trapped white shark from a cage, I would be concerned for lethal removals of white sharks as has been observed in other localities when white sharks became entrapped in fish farming pens (see #1 above).
- Section 8.1. (*General Predator Interactions*) notes that with respect to predators "*Negative interactions can be further divided into two subcategories – those that affect the marine farm populations (predators) and those where the wildlife has been impacted (entangled, entrapped, death).*"
- Section 8.2 (*General Wildlife Interactions*) states that "*Marine birds and mammals have the greatest likelihood for interactions with marine farms given that they share the same waters and migrate through areas where farms are located.*" However, such a statement should equally apply to white sharks in Atlantic Canada as they too share the same waters and migrate through areas where the farms are located. That said, there is little, if any, consideration of, or threat mitigation strategies for white sharks listed in the IWP or elsewhere.
- Section 8.2.1 (*Entanglement, Entrapment*) does not explicitly consider sharks. However, it states "*Marine mammals and large fishes may enter or entangle themselves within netting or anchor lines, either through forceful entry or accidental entanglement.*" Thus, it is possible that "large fishes" apply here to white sharks or could be similarly applied. However, this section only describes management strategies for seals that enter cages, with no similar strategies for "large fishes" or sharks. Specifically, Section 8.2.1 further states that "*Should a marine mammal such as a seal enter a cage, the seal should be immediately released by lowering the net to the height of the float pipe to allow the seal to swim out. The seal should be encouraged to leave the cage from the opposite side*

of the cage from where the net has been dropped." No comparable cage release mechanisms are described for either large fishes or sharks.

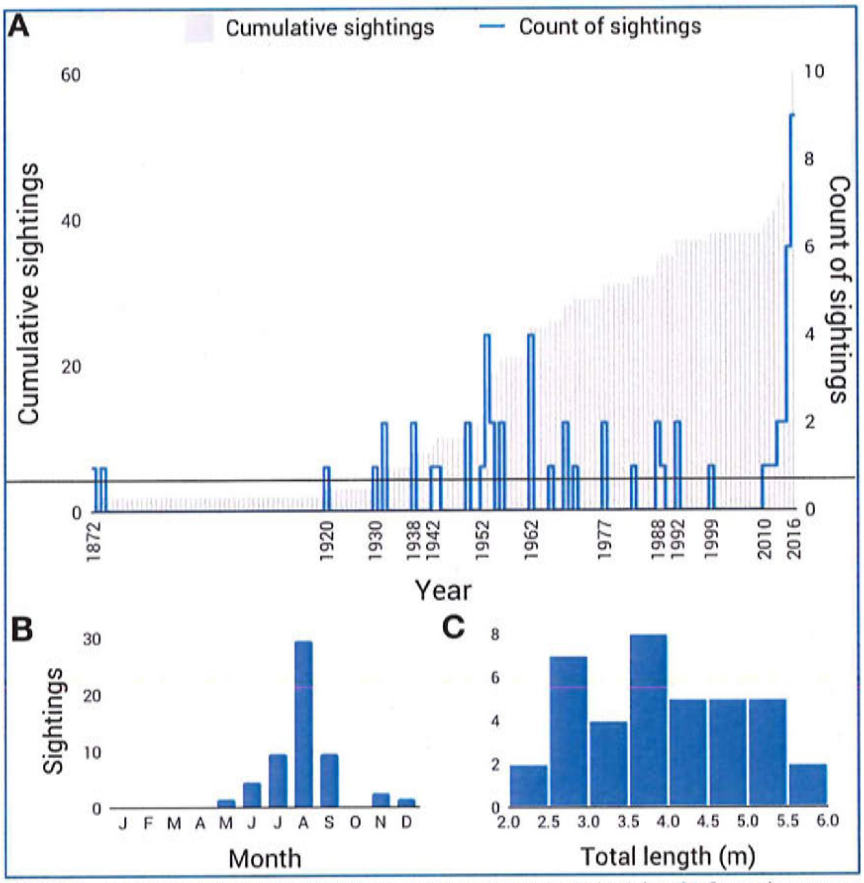

Figure 4. (A) Counts & cumulative white shark sightings in in Atlantic Canada waters for 1872–2016 (B) Monthly distribution of white sharks sightings in Atlantic Canada; (C) Length distribution of sightings in Atlantic Canada; Source: Bastien et al. 2020.

Further notes on netting as it relates to white sharks:

- Table 27 describes the minimum specification requirements for all nets to be used at the farm sites. Note that for the mesh sizes for smolt and market fish has a strength rating of 130 kg and a diameter of 4.2 to 2.6 mm. The predator net (which will not even be deployed during the period of white shark presence in the region) has a mesh strength of 380 kg and a diameter of 3.8 mm.
- A study by Wroe et al. (2008) quantified the bite force of white sharks. For the smallest sexually mature white shark, anterior and posterior bite forces were quantified at 238.7 kg of force and 466 kg of force, respectively. For the largest white shark, anterior and posterior bite forces were quantified at 950.4 kg of force and 1857.5 kg of force, respectively. These bite forces exceed that of the strength rating of the all the nets. The only exception is the predator net and the anterior teeth of a small mature white shark. That said, the predator nets will not even be deployed during the period of white shark presence, which leaves even weaker netting.

- Whether or not the netting will entangle the shark, depends on the flexibility of the netting material. For example, the more flexible the netting, the more likely for a shark to roll the netting around itself. The potential for entanglement also depends on whether the size of the mesh netting, when stretched, would latch on to a fin or tail of the shark and result in a tangle. From the pictures provided in the application documents, I am not able to ascertain on the above. However, as noted above, the proposed netting would likely not be able to withstand the bite of a small mature white shark.

Summary and Conclusion

This report describes the threat posed by the proposed KCS salmon farms in the Liverpool Bay area on white sharks, a species at risk in Atlantic Canada, meaning they are endangered. A review of the scientific literature demonstrates evidence of shark associations globally with ocean-based fish farming. Fish farming exhibits several stimuli that are highly attractive to sharks, including sounds associated with struggling fish and the release of smells from the fish, live or dead, and their feed. The scale of the proposed salmon farming activity, with nearly 2 million fish at any given time, represents an unparalleled source of attractive stimuli within the confined areas of Liverpool Bay. Currently, there are not mitigation measures identified to mitigate these attractive stimuli to white sharks. While cages may be checked once per week for dead salmon that are subsequently removed, with the scale of the operation, just 1% mortality could result in nearly 20,000 dead and decaying salmon at the bottom of the cages for up to a week that would be releasing smells highly attractive to white sharks. In addition to the salmon (dead or alive) in the cages, white sharks may be also attracted to the smell and sounds of other wild fishes and seals that are attracted to the cages. The potential for overlap between white sharks and the farm cages is high, given that Liverpool Bay occurs within high use areas of white sharks, with the water temperatures measured at the cage sites being within the preferred range of white sharks during the late summer and fall, when white sharks seasonally occur in Nova Scotia. Threats to white sharks from the farms include changes in their natural behavior, entanglement and breaching of the pens, which could result in entrapment, injury and/or mortality. Not to mention, if a shark bites through the cage netting, it would cause the escape of farmed salmon, contaminating the wild population, which would be another major issue aside. For example, 13'000 Yellow Tail Kingfish escaped from a farm in South Australia, after a shark attacked the cages and damaged the nets (Scholl and Pade 2005). The proposed predator mitigation techniques as described, would be inefficient at reducing white shark interactions, nor do they appear to have been designed to account for white sharks. While to date, instances of white shark entanglement in fish farms within Atlantic Canada have not yet been reported (DFO 2022), the occurrence of white sharks the region are on the rise (Figure 4) and the likelihood of interactions with the proposed farms is greater given the unparalleled scale of operations close to the shoreline in locations that overlap with white sharks.

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2023 NSUARB 2023-001

This is Exhibit "B" referred to in the Affidavit of Neil Hammerschlag sworn to before me this 19 day of January 2024

[redacted]

Barrister of the Province of Nova Scotia

NATASHA PUKA
A Barrister of the Supreme Court of Nova Scotia

Neil Hammerschlag, Ph.D.
Curriculum Vitae

Higher Education:

Institutional

- University of Miami, Rosenstiel School of Marine and Atmospheric Science; Doctor of Philosophy, Marine Biology & Fisheries; December 2009
- Nova Southeastern University, Oceanographic Center; Master of Science, Marine Biology; May 2004
- University of Toronto, Canada; Bachelor of Science; Ecology, May 2002

Certification, Licensure

- PADI Master Scuba Diver
- PADI Rescue Scuba Diver
- PADI Open-water Scuba Diver
- AAUS Scientific Diver
- MOCC Motorboat Operation Certification

Experience

Academic

- Marine Biodiversity Observation Network; Investigator and Working Group Co-Lead (BioTrack and BioSound); 2019-Present
- Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; Research Associate Professor, 2018-2022
- Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; Research Assistant Professor, 2010-2017
- Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, Graduate Research Assistant; 2004-2009
- Pew Institute for Ocean Science, University of Miami; Graduate Research Assistant; 2004-2006
- Nova Southeastern University, Oceanographic Center; Undergraduate Teaching Assistant; 2003
- Nova Southeastern University, Oceanographic Center; Graduate Teaching Assistant; 2004

Non-Academic

- Atlantic Shark Expeditions; Nova Scotia, Canada; Owner/President; 2022-Present
- Black Girls Dive Foundation; Science Faculty; 2021-Present
- ReefQuest Marine Projects, Vancouver Canada; Expedition Leader; 2003-2004

Peer-Reviewed Publications (Total = 150, Citations = 8144, h-index = 51, ih10-index = 116)

Juried or refereed articles (Trainees are underlined)

150 Cottrant E, Elston C, Watson RGA, Morrison JH, Drobniewska NJ, Underhill LG, Murray TS, Albano PS, **Hammerschlag N.**, et al. (In Press) Ontogenetic shifts in the movements of the spotted gully shark (*Triakis megalopterus*) in the Western Cape, South Africa; *African Journal of Marine Science*

149 Sulikowski JA, **Hammerschlag** N. (2023) A novel intrauterine satellite transmitter to identify parturition in large sharks. *Science advances*. 9(9):eadd6340.

148 Faure-Beaulieu N, Lombard AT, Olbers J, Goodall V, da Silva C, Daly R, Jordaan G, Kerwath SE, ...**Hammerschlag N** et al. (2023) A systematic conservation plan identifying critical areas for improved chondrichthyan protection in South Africa. *Biological Conservation*; 284:110163.

147 Albano PS, Fallows C, Fallows M, Williams LH, Murray T, Sedgwick O, **Hammerschlag N.** (2023) Acoustic tracking of a threatened juvenile shark species, the smooth hammerhead (Sphyrna zygaena), reveals vulnerability to exploitation at the boundary of a marine reserve. Frontiers in Marine Science. 2023 Feb 6;10:72.

146 Wosnick N, Prado AC, Martins M, Merly L, Chaves AP, **Hammerschlag N**, Shipley O, Hauser-Davis RA. (2023) Reviewing Cd, Hg and Pb Assessments and Effects in Elasmobranchs. *In Lead, Mercury and Cadmium in the Aquatic Environment* (pp. 46-75). *CRC Press*.

145 Cooke SJ, Galassi DM, Gillanders BM, Landsman SJ, **Hammerschlag N**, Gallagher AJ, Eliason EJ, Kraft CE, Taylor MK, Crisafulli CM, Shugar DH. (2022) Consequences of "natural" disasters on aquatic life and habitats. *Environmental reviews;* 31(1):122-40.

144 Shinder SL, Cray C, **Hammerschlag N**, Merly L. (2022) Serum protein electrophoresis reference intervals for six species of wild-sampled sharks in South Florida. *Integrative and comparative biology*; 62(6):1547-56.

143 Renshaw S, **Hammerschlag N**, Gallagher AJ, Lubitz N, Sims DW. (2023) Global tracking of shark movements, behaviour and ecology: A review of the renaissance years of satellite tagging studies, 2010–2020. Jou*rnal of Experimental Marine Biology and Ecology;* 560:151841.

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43 Gallagher AJ, **Hammerschlag N**, Cooke SJ, Costa DP, Irschick DJ. (2015) One size does not always fit all: a reply to Stroud and Feeley. *Trends in Ecology and Evolution*; 30(6): 297-298.

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37 Irschick DJ, **Hammerschlag N**. (2014) A new metric for measuring condition in large predatory sharks; *Journal of fish biology;* 85(3), 917-926.

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35 Shiffman DS, **Hammerschlag N**. (2014) An assessment of the scale, practices, and conservation implications of Florida's charterboat-based recreational shark fishery; *Fisheries*; 39(9): 395-407.

34 Shiffman DS, Gallagher AJ, Wester J, Macdonald C, Thaler AD, Cooke SJ, **Hammerschlag N**. (2014) Trophy fishing for species threatened with extinction: a way forward building on a history of conservation; *Marine Policy*; 50: 318-322.

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25 **Hammerschlag N**, Luo J, Irschick DJ, Ault JS. (2012) A Comparison of Spatial and Movement Patterns between Sympatric Predators: Bull Sharks (*Carcharhinus leucas*) and Atlantic Tarpon (*Megalops atlanticus*); *PLOS ONE* 7(9): e45958.

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23 Fallows C, Gallagher AJ, **Hammerschlag N**. (2013) White Sharks (*Carcharodon carcharias*) Scavenging on Whales and Its Potential Role in Further Shaping the Ecology of an Apex Predator; *PLOS ONE* 8(4): e60797. doi:10.1371/journal.pone.0060797.

22 Shiffman DS, Gallagher AJ, Boyle MD, Hammerschlag-Peyer CM, **Hammerschlag N**. (2012) Stable Isotope Analysis as a Tool for Elasmobranch Conservation Research: A Primer for Non-Specialists; *Marine and Freshwater Research;* 63:635-643.

21 Gallagher AJ, Kyne PM, **Hammerschlag N**. (2012) Ecological risk assessment and its application to elasmobranch conservation and management; *Journal of Fish Biology*; 85(5): 1727-1748.

20 Martin RA, **Hammerschlag N**. (2012) Marine predator–prey contests: Ambush and speed versus vigilance and agility; *Marine Biology Research*; 8:1, 90-94

19 Mondo K, **Hammerschlag N**, Basile M, Pablo J, Banack SA, Mash DC. (2012) Cyanobacterial Neurotoxin β-N-Methylamino-L-alanine (BMAA) in Shark Fins; *Marine Drugs*; 10(2), 509-520.

18 Fallows C, Martin RA, **Hammerschlag N**. (2012) Comparisons between white shark-pinniped interactions at Seal Island (South Africa) with other sites in California (United States). *In:* Global Perspectives on the Biology and Life History of the White Shark, ed. Michael L. Domeier; Chapter 9, *CRC Press*, Boca Raton, FL.

17 **Hammerschlag N**, Martin RA, Fallows C, Collier R, Lawrence R. (2012) Investigatory Behavior towards surface objects and Non-consumptive Strikes on Seabirds by White Sharks (*Carcharodon carcharias*) at Seal Island, South Africa (1997-2010 *In:* Global Perspectives on the Biology and Life History of the White Shark, ed. Michael L. Domeier; Chapter 8, *CRC Press*, Boca Raton, FL.

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14 **Hammerschlag N**, Sulikowski J. (2011) Killing for Conservation: The Need for Alternatives to Lethal Sampling of Apex Predatory Sharks; *Endangered Species Research*; 14: 135-140.

13 Gallagher AJ, **Hammerschlag N**. (2011) Global Shark Currency: The Distribution, Frequency and Economic Value of Shark Eco-tourism; *Current Issues in Tourism*; 1–16.

12 **Hammerschlag N**, Gallagher AJ, Lazarre DM. (2011) A Review of Shark Satellite Tagging Studies; *Journal of Experimental Marine Biology and Ecology*; 398(1-2): 1-8.

11 **Hammerschlag N**, Gallagher AJ, Lazarre DM, Slonim C. (2011) Range extension of the endangered great hammerhead shark *Sphyrna mokarran* in the Northwest Atlantic: Preliminary data and significance for conservation; *Endangered Species Research*; 13: 111-116.

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(BMAA) in South Florida Aquatic Food Webs; *Harmful Algae*; 9: 620-635

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7 **Hammerschlag N**, Morgan AB, Serafy JE. (2010) Relative predation risk for fishes along a subtropical marine ecotone; *Marine Ecology Progress Series*; 401: 259-267.

6 **Hammerschlag N**, Serafy JE. (2010) Nocturnal fish utilization of a subtropical mangrove-seagrass ecotone: stage-specific patterns of abundance in four species; *Marine Ecology*; 31: 364-374.

5 Martin RA, Rossmo DK, **Hammerschlag N**. (2009) Hunting Patterns and Geographic Profiling of White Shark Predation; *Journal of Zoology*; 279: 111-118.

4 **Hammerschlag N**, Martin RA, Fallows C. (2006) Effects of environmental conditions on predator-prey interactions between white sharks (*Carcharodon carcharias*) and Cape fur seals (*Arctocephalus pusillus pusillus*) at Seal Island, South Africa; *Environmental Biology of Fishes*; 76: 341-350.

3 **Hammerschlag N**. (2006) Osmoregulation in Elasmobranchs: A review for fish biologists, behaviourists and ecologists; *Marine and Freshwater Behaviour and Physiology*; 39(3): 209-228.

2 **Hammerschlag N**, Fallows C. (2006) Galapagos sharks (*Carcharhinus galapagensis*) at the Bassas da India atoll: first record from the Mozambique Channel and possible significance as a nursery area; *South Afr. Journal of Science*; 101: 375-377.

1 Martin RA, **Hammerschlag N**, Collier R, Fallows C. (2005) Predatory Behaviour of White Sharks (*Carcharodon carcharias*) at Seal Island, South Africa; *Journal of the Marine Biological Association of the UK*; 85: 1121-1135.

Professional and Honorary Organizations (member; officer; date):

- The American Elasmobranch Society (AES); Member; 2002-Present
- The Explorers Club; National Fellow; 2004-2008
- Society for Integrative and Comparative Biology; Member, 2014-2015
- Global Shark Movement Project; collaborative member; 2015 to Present

- Marine Biodiversity Observation Network; Investigator, 2019 to Present
- Ocean Tracking Network, member partner; 2017 to present

Academic Achievements, Honors and Awards:

- Invited Keynote Speaker
  - *International User Conference on Argos Wildlife Applications* (Baltimore Maryland, USA, 2014)
  - *European Elasmobranch Association Annual Meeting* (Amsterdam, Netherlands; 2017)
  - *Shark International Conference* (João Pessoa, Brazil; 2018)
  - *Morris Kahn Marine Research Station Seminar Series* (Haifa, Israel; 2018)
  - *Fifth International Whale Shark Conference* (Exmouth, Western Australia; 2019)
- Scientific Advisor of first international symposium on *Fish at Night* (Miami, Florida USA; 2015)
- Guest Editor of *Bulletin of Marine Science* on the published Proceedings of the *Fish at Night International Symposium* (Volume 93, Issue 2)
- U-Link Fellow; University of Miami; 2019
- Provost Research Award; University of Miami; 2017
- Best Student Publication in Division of Marine Biology and Fisheries; Rosenstiel School of Marine and Atmospheric Science; 2009
- The Don de Sylva Award for Excellence in Fisheries Research; Rosenstiel School of Marine and Atmospheric Science, University of Miami; 2008

Teaching

- ECS111 (Introduction to Earths Ecosystems); Fall 2010.
- MAF671/ECS572 (Marine Conservation Biology: An Ecosystem-based Paradigm); 2011 to 2017
- CVJ595/ECS 572 U33 (Applied Visual Science Lab); Spring 2015.
- CVJ650/ECS (3D Design & Infographics); Spring 2016 & 2017
- MES534/634 (Shark Behavioral Ecology & Conservation); Spring 2018 to present
- MSC105 (Shark Behavioral Ecology): Summer B 2019 to present
- Marine Conservation Track for Professional Masters Program (MPS) at RSMAS; I helped develop this track and currently serve as a track advisor.

Thesis and Dissertation Advising:

Doctor of Philosophy (Ph.D.)

1. Chair of Ph.D. Committee, Austin Gallagher: *Shark vulnerability to fishery interactions: assessing ecological, physiological, and social risks*; 2015 graduated.
2. Chair of Ph.D. Committee, David Shiffman: *Ecosystem importance, population declines, policy solutions, and stakeholder attitudes towards each: An integrative and interdisciplinary approach to shark conservation*; 2016 graduated.
3. Chair of Ph.D. Committee, Rachel Skubel: *An integrative risk assessment of climate change effects on the habitat use and physiology of highly mobile marine apex predators*; 2021 graduated.
4. Chair of Ph.D. Committee, Laura Mcdonnell: *Integrating shark borne-sensor data into the ocean observing toolkit: implications for monitoring climate variability and implementing dynamic fisheries management*; 2022 graduated.
5. Co-Supervisor of Ph.D. Committee, Bianca Rangel (University of São Paulo): *Ecophysiology and trophic relationships of sharks: biomarkers as tools for conservation*; 2022 graduated.
6. Member of Ph.D. Committee, Alexandra Norelli: *Assessing the Dynamics of Mixed School Tropical Tuna to Reduce Juvenile Mortality from Surface Fleets*; 2022 graduated.
7. Co-Chair of Ph.D. Committee, Mitchel Rider: *Understanding the Movement Ecology of Leatherback Sea Turtles (Dermochelys coriacea) along the Northwest Atlantic shelf*; 2023 graduated.
8. Member of Ph.D. Committee, Brooke Anderson (Arizona State University): *Using satellite tagging technologies to improve management and conservation of the Northwest Atlantic porbeagle Lamna nasus*; 2024 expected graduation.
9. Member of Ph.D. Committee, Chelsea Black: *Monitoring Marine Biodiversity Hotspots and Migration Corridors of Highly Mobile Shark Species Under Global Change*; 2024 expected graduation.

Master of Science (M.S.)

1. Member of M.S Committee; Rachel Kraemer (Northeastern University): *A description of the shark community around the upper-middle Florida Key and how differing level of marine protection influence distribution*; 2010 graduated.
2. Member of M.S Committee; Julia Lampe: *Developing and instituting a shark biology/ecology program for the Marjory Stoneman Douglas Biscayne Nature Center*; 2011 graduated.
3. Chair of M.S. Committee; Fiona Graham: *Quantifying habitat protection and assessing MPA network functionality for shark Species in South Florida*; 2013 graduated.

4. Co-Chair of M.S. Committee; Brittany Bartlett: *Sea turtle protection in the Eastern Equatorial Pacific: a strategy to reduce incidental take and promote conservation;* 2013 graduated.
5. Chair of M.S. Committee; Hannah Calich: *Spatiotemporal vulnerability of large sharks to longline fisheries in the Subtropical Atlantic Ocean and Gulf of Mexico;* 2016 graduated.
6. Chair of M.S. Committee; Alison Enchelmaier: *Survey of Mangrove Flora and Fauna of Bill Baggs State Park, Key Biscayne, FL;* 2016 graduated.
7. Chair of M.S. Committee, Stacy Assael: *Factors effecting long distance movements of tiger sharks;* 2016 graduated.
8. Chair of M.S. Committee; Jake Jerome: *Integrating Physiological and Behavioral Biomarkers of Fishing Capture Stress in Coastal Shark Species;* 2016 graduated.
9. Member of M.S. Committee; Patrick Goebal: *Distribution, Abundance and Movement of Predators among Seagrass and Mangrove Habitats in Biscayne Bay;* 2016 graduated.
10. Chair of M.S. Committee; Leila AtallahBenson: *Isolation and characterization of c-reactive protein in wild nurse sharks, Ginglymostoma cirratum: a potential wild shark health biomarker;* 2017 graduated.
11. Chair of M.S. Committee; Robert Roemer: *Urban Shark- The effects of human-induced stressors on the ecology of sharks occupying urbanized landscapes;* 2018 graduated.
12. Chair of M.S. Committee; Emily Nelson: *Functional morphology and individual variation in movement performance of apex marine predator;* 2018 graduated.
13. Member of M.S. Committee, Kelsey Spencer: *Coastal Shark Movements near Fishing Piers along the NE Coast of South Carolina;* 2018 graduated.
14. Chair of M.S. Committee, Shannon Moorhead: *Body and nutritional condition in nurse sharks (Ginglymostoma cirratum) sampled across an urban gradient in Biscayne Bay, Florida;* 2019 graduated.
15. Chair of M.S. Committee, Mitchel Rider: *Habitat use of coastal sharks in response to boat trafic in Biscayne Bay, Florida;* 2020 graduated.
16. Chair of M.S. Committee, Chelsea Black: *Investigating bacterial communities within the microbiome of sharks in Biscayne Bay, Florida;* 2020 graduated.
17. Member of M.S. Committee, Elana Rusnak: *Acute phase proteins in the nurse shark, Ginglymostoma cirratum;* 2020 graduated.
18. Chair of M.S. Committee, Patricia Albano: *Evaluating the Efficacy of a Marine Reserve for Endemic and Threatened Sharks off South Africa;* 2020 graduated.
19. Chair of M.S. Committee, Gaitlyn Malone; *Investigating the spatial and diel patterns in teleost foraging behavior across an urban gradient;* 2021 graduated.

20. Chair of M.S. Committee, Lacey Williams; *Evaluating the natural predatory interactions between great white sharks and Cape fur seals in Plettenberg Bay, South Africa*; 2022 graduated.
21. Chair of M.S. Committee, Abigail Tinari; *Physiological and biological investigations into pervasive pollutant effects associated with marine urbanization: artificial light and anthropogenic noise*; 2022 graduated.
22. Chair of M.S. Committee, Alexandra Anstett; *Assessing the Conservation Benefit of Addo Elephant National Park Marine Protected Area in Algoa Bay, South Africa*; 2022 graduated.
23. Member of M.S. Committee, Sophia Del Porto: *Heavy metal stress and health parameters in coastal sharks of South Florida*; 2022 graduated.
24. Chair of M.S. Committee, Yakira Gerszberg; *Investigating the loss of an apex predator in the wild on the behavioral responses of a marine community*; 2022 graduated.

Master of Professional Science (M.P.S.)

1. Supervisor of M.P.S Committee, Piper Wallingford; Northeastern University; 2011 graduated.
2. Chair of M.P.S. Committee, Jordan Creed: *City of Miami Beach Dune Management Plan*; 2012 graduated.
3. Member of M.P.S Committee, Jennah Caster: *Saving sharks: projects to promote conservation awareness and citizen science*; 2012 graduated.
4. Supervisor of M.P.S. Committee, Rebecca Shelton; Northeastern University: *Non-consumptive effects of conspecifics and predatory fish on blue crabs affect shelter use and mortality*; 2013 graduated.
5. Member of M.P.S Committee, Shannon Jones: *Enhancing AOML Science Communications via Social Media Platforms*; 2014 graduated.
6. Member of M.P.S Committee, Mary Trainor: *Data-poor fisheries management*; 2014 graduated.
7. Chair of M.P.S. Committee, Andrew Blitman: *A comparative analysis of highly migratory species regulation in the wider Caribbean basin; and the potential for regulatory reform and regional agreements to foster the protection of billfish within the Caribbean;* 2014 graduated.
8. Member of M.P.S Committee, Dalton Hesley: *Enhancing the Rescue A Reef Program through Social Media, Education, and Outreach*; 2015 graduated.
9. Chair of M.P.S. Committee, Hannah Armstrong: *Visual Science Communications: Disseminating Timely Marine Conservation Issues to Increase Awareness Among the General Public*; 2015 graduated.
10. Chair of M.P.S. Committee, Stephen Cain: *Program Evaluation in an Informal*

Enviro-ed Program: Shark Research and Conservation at UM; 2016 graduated.

11. Chair of M.P.S. Committee, Andriana Fragola: *Microflora found on the epithelial layer of Carcharhinus limbatus and Carcharhinus leucas in healthy and unhealthy regions of their body*; 2018 graduated.
12. Chair of M.P.S. committee, Haley Kilgor: *Changes in size over time and depth of three popularly fished species in Biscayne National Park*; 2019 graduated
13. Committee member of M.P.S.; Jeff Palumbo: *Utilizing Technology for Underwater Data Acquisition in Exploration Sciences*; 2018 graduated.
14. Chair of M.P.S. Committee, Jay Dawsey: *Methods to evaluate marine protected area efficacy for Chondrichthyan conservation;* 2020 graduated.
15. Member of M.P.S Committee, Victor Bach Munoz: *Among Fins Documentary Film Project*; 2021 graduated.
16. Chair of M.P.S. Committee, Quartz Clark: *Seas by Degrees: A Graduate Student Seminar Series*; 2021 graduated.
17. Chair of M.P.S. Committee, Camilla Smith: *Bringing the Ocean Online: Multimedia Tools for the Shark Research and Conservation Program at the University of Miami*; 2021 graduated.
18. Chair of M.P.S. Committee, Valerie Zundel: *Use of Social Media to Engage Large and Diverse Audience in Shark Science During COVID-19 Pandemic*; 2021 graduated.
19. Chair of M.P.S. Committee, Omar Ramzy: *Targeted Learning Communities: A Cohort Focused Approach to Closing Disparities in Marine Science*; 2022 graduated.
20. Member of M.P.S Committee, Miasara Andrew-Nandlall: *Evaluating effects of dissolved oxygen on the movements of sharks in the Gulf of Mexico*; 2022 graduated.
21. Member of M.P.S Committee, Nicolás Febres-Cordero: *Using video to strengthen scientific communication and outreach for the University of Miami Shark Research & Conservation Program*; 2022 graduated.

Community Activities and Service:

- **National Marine Fisheries (NMFS) Service SEDAR Pool (2020-2025):** I was recently selected to serve as a member of the NMFS Atlantic Highly Migratory Species Southeast Data, Assessment, and Review (SEDAR) Workshop Advisory Panel. I am currently serving as a panel member for of hammerhead shark stock assessment (SEDAR 77) in the Atlantic Ocean and Gulf of Mexico. My responsibilities include provide insights and scientific information at SEDAR workshops to support stock assessments.

- **Innovative teaching and training:** In 2010, I established and directed the Shark Research and Conservation Program (SRC) at the University of Miami. The goal of the program is to foster scientific literacy and environmental ethic in youth and the public by providing exciting hands-on field research experiences in shark conservation biology. I accomplish this by providing school groups with exciting hands-on experience in my research. Over the last 10 years, we have taken over 10,000 people, mostly school kids, on boats to participate in practical hands-on research, including underserved kids and even "last chance" alternative learning facilities for juvenile offenders.
- **Development of curricular materials**: I helped develop an online middle school curriculum in Marine Conservation Science & Policy that is available free for download from our website. Additionally, I helped design and now serve as a track coordinator for University of Miami's Professional Masters Program in Marine Conservation. Further, I created and teach a graduate course in *Shark Behavioral Ecology and Conservation*. I also co-developed and have taught a course in science communication
- **Science communication and public engagement:** I am passionate about effective science communication using traditional and innovative approaches. Besides regularly giving public seminars, I also use broadcast and social media to communicate my research and reach a large audience. For example, I frequently work with television networks, such as Discovery Channel and National Geographic, to generate documentaries. I am also participant and winner of the Ocean 180 Video Challenge, a platform funded by NSF designed to engage non-scientists and students in timely and relevant ocean science research through short films. Films are watched and evaluated by over 30,000 middle school students from around the world. As a winner of Ocean 180 Video Challenge, participated in a live interactive chat with over 1000 middle school students about science.
- **Advisory Committee for Digital Life3D**, a non-profit initiative within the University of Massachusetts at Amherst that creates digital 3D models of living organisms to support wildlife conservation, science, and education.
- **Co-lead of Marine Biodiversity Observation Network (MBON) Working Groups:** I established and co-lead two working groups for the U.S. MBON: "BioTrack" and "BioSound". The former is focused on novel application of animal tracking data for biodiversity monitoring and assessments. The latter aims to streamline and standardize the metrics that are useful to biologists and managers that can be derived from ocean sound. These efforts involve the engagement of numerous stakeholders, including industry, academia, and management.
- **Diversity, Equity and Inclusion**: I am committed to being a leading advocate

for supporting diversity in academia and S.T.E.M. more broadly. Activities I have engaged in to support diversity, equity, and inclusion (DEI), include acquiring formal training in racial and cultural competence and establishing a student-lead DEI committee within my own lab group. I also currently serve as an invited Science Faculty for the *Black Girls Dive Foundation,* where I create curricular materials for participating girls as well as lead S.T.E.M.-based dive eco-adventures.