Flotsam & Jetsam

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Endangered Ocean: Sharks

NOAA Fisheries

Did you know that sharks have existed for more than 400 million years? There are more than 450 species of sharks throughout the ocean and they come in all different colors and sizes.

The whale shark is the largest. It can grow to more than 40 feet – that's as large as a school bus. At a mere six inches, the dwarf lantern is one of the smallest sharks and can fit in the palm of your hand.

What sharks do have in common is the role they play in their ecosystems. Most sharks are apex predators and sit at the top of the food chain. They play a vital role in keeping the ecosystem healthy by feeding on animals that are lower in the food chain.

Sharks take many years to mature, have only a few young at a time, and are highly migratory. What makes them unique also makes them vulnerable.

While the majority of shark species have sustainable populations, a number of them have been shrinking at an alarming rate. For these species, overfishing, bycatch, and shark finning are contributing factors in their decline.

But thanks to a global, growing awareness about vulnerable shark species, many countries are implementing shark fin bans – even in places where shark fin soup is considered a delicacy and cultural tradition.

Countries around the world have been working together to promote the adoption of shark conservation and management measures. In March of 2013, as a result of tremendous international cooperation, five shark species were listed by CITES—an international organization. This means increased protection for these particular sharks, while still allowing legal and sustainable trade.

A healthy ocean needs healthy shark populations — and endangered sharks need our help.

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If you have difficulty accessing this journal, contact the editor at dimmick@esteacher.org . The next issue of *F&J* will be posted on the website on Sept. 8.

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c/o Robert Rocha, New Bedford Whaling Museum
18 Johnny Cake Hill, New Bedford, MA 02740
www.ma-marine-ed.org

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2019 MME Summer-Fall Calendar

Check website and F&J for details.

SEPTEMBER 11
MME Board Meeting
New England Aquarium
Corrine Steever, hostess
csteever@neaq.org

OCTOBER 5
Boston Harbor Educators Conference
A Working Harbor: Past, Present, and Future
Deer Island Wastewater Plant
Winthrop, MA
To register please click on massmarineeducators.wufoo.com/forms/rjzdr621envy45/

NOVEMBER 12
MME Board Meeting
Revere High School
Don Pinkerton, host
DPinkerton@rpsk12.org

All MME Members are invited to Board Meetings.
Let the host know if you are coming.

Seasonal Distribution and Historic Trends in Abundance of White Sharks, *Carcharodon carcharias*, in the Western North Atlantic Ocean

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Tobey H. Curtis , Camilla T. McCandless, John K. Carlson, Gregory B. Skomal, Nancy E. Kohler, Lisa J. Natanson, George H. Burgess, John J. Hoey, Harold L. Pratt Jr.

Introduction

The white shark *Carcharodon carcharias* is one of the largest, most widespread ocean predators distributed in sub-polar to tropical seas of both hemispheres. White sharks are important apex predators that occupy trophic levels similar to that of carnivorous marine mammals (trophic level = 4.5). While white shark productivity (expressed as intrinsic rates of increase or population rebound potentials) falls along the midpoint of a continuum of productivity values calculated for a suite of shark species, they may have naturally low abundance and possess general life history traits that make them vulnerable to exploitation. Although white sharks have not historically been subjected to directed fisheries, there are numerous accounts of incidental captures in commercial fisheries worldwide. Moreover, their iconic status and highly valued jaws and fins have subjected them to targeted recreational and trophy fisheries where or when their populations have been unprotected.

To date, only Baum et al. and McPherson and Myers have attempted any quantitative assessment of the status of the white shark population in the northwest Atlantic Ocean (NWA). While some of these results have been criticized as unreliable and overly pessimistic, analysis of pelagic longline fishery logbook data from the NWA suggested a sharp decline (between 59 and 89%) in white shark numbers between 1986 and 2000. Similarly, using sparse sightings data (N=31) from Atlantic Canada, McPherson and Myers estimated a 3-fold increase in white shark population size between 1926 and 1988. Due to studies such as these, evidence of population declines in other regions around the world and their iconic and charismatic nature, white sharks have been afforded some of the highest level of protection of any elasmobranch. For example, they have been listed on the appendices of The United Nations Convention on Law of the Sea (UNCLOS), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Convention for the Conservation of Migratory Species (CMS). The World Conservation Union (IUCN) currently lists the white shark globally as 'Vulnerable'. In the NWA, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recommended that white sharks be listed as "Endangered," and they have been listed as a prohibited species (i.e., no commercial or recreational harvest) in US waters since 1997. Due to these conservation concerns, and the high uncertainty associated with previous studies, there is a need to better understand the historic and current status of white sharks in the NWA, incorporating as much reliable data as possible.

Despite recent advances in field research on white sharks in several regions around the world, opportunistic capture and sighting records remain the primary source of information on this species in the NWA. This is due to their sparse distribution and a historic lack of discrete coastal aggregation sites in this region. Casey and Pratt provided a qualitative assessment of the distribution of NWA white sharks, but this study took place before the significant expansion in the 1980s of directed large coastal shark fisheries in the US Atlantic. White sharks were found to range from Newfoundland, Canada to the Gulf of Mexico and northern Caribbean Sea, but were most frequently encountered from the Gulf of Maine south to Cape Hatteras, North Carolina. They have been considered only occasional visitors to the warmer waters off the southeastern US and Gulf of Mexico.

Herein, we report on the patterns of distribution and relative abundance of white sharks in the NWA region based on a comprehensive compilation of historic and recent white shark capture and sighting records. A variety of fishery-dependent and -independent sources were synthesized, resulting in the largest white shark dataset yet compiled from this region. We provide a robust description of their historical abundance trends, spatio-temporal distribution, fishery interactions, and essential habitats. This updated information will improve the conservation and management of white sharks regionally and internationally, and provide a new baseline for future studies.

Methods

White shark occurrence records were collected from numerous sources, including landings data, commercial fishery observer programs, recreational tournament information, scientific

continued on page 10

President's Message

Greetings,

I am very excited to be taking on the role of President of MME. I am so proud of this organization and am looking forward to spending the next two years at the helm. A little background information: I am a classroom teacher at Revere High School, where I teach biology to English language learners, freshman honors biology, and a biotechnology elective to seniors. I am passionate about marine science and make every effort to include marine science topics wherever I can in my curriculum. I have been at RHS for about ten years, after a career change. I live by the philosophy that in order to enjoy being an effective teacher, you have to love what you teach, and you have to love your students. That can be a real challenge some days! But these are two necessary conditions for teaching success, and I try to remind myself of them daily.

I am fortunate to be supported by an excellent Board of Directors at MME. I want to especially thank Anne Smrcina for her leadership and guidance for the past two years. We are a stronger organization for her efforts. Anne will be continuing as Past-president for the next two years so we will still have the advantage of her wisdom and experience. We are hoping to identify a President-elect soon. We do have a few open seats for the board, so please let me know if you are interested in joining us.

Here are my goals for MME for the next two years:

1. Increase the value members receive from MME. Professional organizations such as MME are facing many challenges in the digital age. In the past, educators would look to MME and similar groups for lesson plans, classroom activities, and to increase content expertise. Many of these resources are now available at the click of a mouse. As we look to the future, I believe MME can offer educators virtual and physical space to collaborate and share ideas on an area of science we are all passionate about. We will be looking to offer more informal opportunities to get together, such as educator field trips, meet-ups, and lectures. We are also exploring more opportunities to collaborate in the virtual world, such as webinars and other distance learning venues.
2. Increase member engagement. Most of the work of MME is performed by the Board of Directors. But joining the MME board might be more of a commitment than some of you are willing to take on. My goal is to help those of you who WANT to be more involved do so without scaring you away! There is so much we can accomplish if we work together.
3. Improve our communications and increase our social media presence. We will be looking at all aspects of how we communicate, including the web site, e-news, publications, and social media postings.

We will be holding a full-day, professionally facilitated board retreat on June 29, where we will explore these and other goals. Our objective is to define the mission of Massachusetts Marine Educators for 2020 and beyond. No small task, for sure! I look forward to the challenges and opportunities ahead, and to insuring that MME lives up your high expectations.

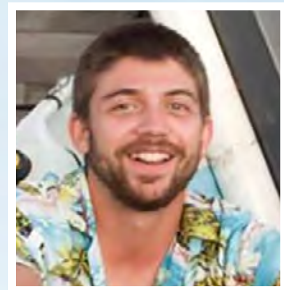
Best regards,

Don

Meet Your New Board Members

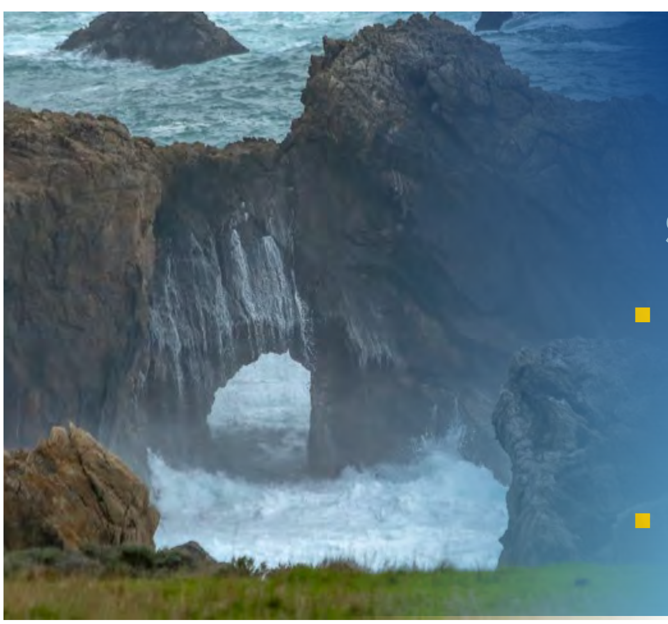
Emily Hewitt

Emily Hewitt is a secondary school teacher. She has taught for nine years in independent schools and is presently teaching science at The Academy at Penguin Hall where she engages students in creative activities, encourages them to take active roles in their communities, and challenges them to think in nontraditional ways. Emily designed an interdisciplinary activity to understand the dangers of plastic pollution through creating art from waste, she led a beach clean up on the North Shore with her students, and developed an interdisciplinary course about whales and whaling. She graduated from Wellesley College with concentrations in Environmental Science and Geoscience. As an undergraduate, Emily traveled to Lake Baikal in Russia to participate in a month long field study of endemic detritivores. She investigated the effects of island mass effect on the density and distribution of zooplankton as her research project while a Sea Education Association student when she sailed from Tahiti to Hawaii. Emily also taught marine science and sailing in environmental education programs. She is a MME member and has attended the Woods Hole and Boston conferences. Emily presented a workshop related to ocean acidification at the most recent Boston Harbor conference. She is excited to take on a more active role in the organization.



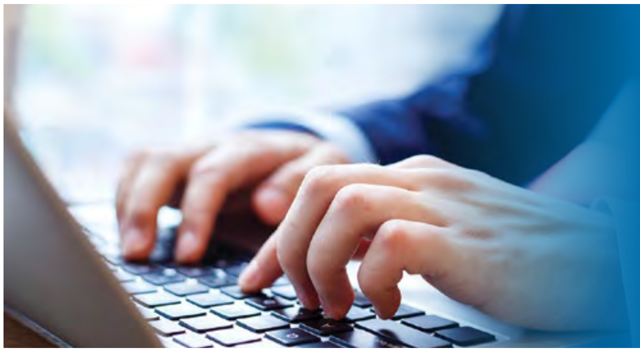
Jeffrey Morgan

Jeffrey Morgan studied Marine Science at Boston University (BU). While at BU, he completed two transatlantic oceanographic research trips, studying plankton, with Sea Education Association and worked in the Fulweiler Lab studying biogeochemistry. Currently, Jeffrey is the Executive Director of Ocean Protection Advocacy Kids, Inc. (OPAK), a nonprofit he Co-Founded in 2016. OPAK empowers youth to become curious ambassadors for the environment through the arts. Before starting OPAK, he was the Assistant Director of The Global Warming Express Cape Cod where he developed ocean-based curriculum for 8-12 year olds. Jeffrey also sits on the Board of Directors of the Friends of Pleasant Bay and spent five summers teaching marine science aboard tall ships on the east coast. He is a strong advocate of communicating science which is what brought him into the education world. When not teaching, he enjoys sailing and hiking with his Portuguese Water Dog.



OCEAN LITERACY PRINCIPLE 2:
The ocean and life in the ocean shape the features of the Earth.

- Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.
- Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.



From the Editor's Desk

Another school year is coming to an end. (Probably will be over when this issue is posted.) I must take time to apologize for the lateness of this journal. Early in May, I suffered an injury which required me to spend several days in a rehab facility. It just happened that it was the two+ weeks when I was working on a journal. On returning to the computer, I am sure you can imagine what my e-mail list looked like (over 500 e-mails) and the time it took to answer them and collect the materials for this issue. Now that I am back and catching up, the journal is in final stages of being sent to Page Designs for final preparation.

This issue deals with Sharks, and specifically the Great White is highlighted. With the help of NOAA and NOAA Fisheries I was able to collect materials for the Journal. In addition, there are several articles dealing with the 2019 Marine Art Contest with Anne receiving over 500 entries this year from New England, PLUS Michigan, Texas and also from China. Some great art work was presented to the Judges to declare the winners. In this issue you will find the list of the winners and over the coming year you will see some of the artwork in this Journal as well as in a traveling exhibit that Anne brings around the state for display.

You will also meet the new Board Members and the award winners from the Annual Meeting. Congratulations to the winners, and welcome aboard to the new Board Members. I also need to take time to thank our outgoing president, Anne Smrcina, for her help in getting materials and contacts to me for the journal. She has worked hard behind the scenes on the journal as she also was serving as president. This is in addition to her full-time position at Stellwagen Bank National Maine Sanctuary,

As the summer progresses, you will get information about the fall Boston Harbor Educators Conference in October. This year, it is at a new location, at the MWRA facility on Deer Island in Winthrop. New Location, new program, so keep it in mind and keep the date October 5 open. Conference theme is A Working Harbor: Past, Present, and Future

An additional location for materials about sharks is the Atlantic White Shark Conservancy (http://www.atlanticwhiteshark.org/). At this website you will find the following:

- **Sharktivities** Printable worksheets for your classroom
- **Shark Heroes** Printable infographics introducing your class to Shark scientists and their work
- **Grade 3 Shark Unit** A full unit on sharks aligned with next gen standards
- **Algebra: Calculating White Shark Populations** This uses mock data to help students fuse data.
- **Shark Week Curriculum for High Schools** This unit is designed for a high school biology, marine biology or environmental science course.
- **Educational Videos** What is a Shark and How do Sharks find their prey?

Enjoy the summer. I look forward to seeing you in the fall.

Howard
Editor

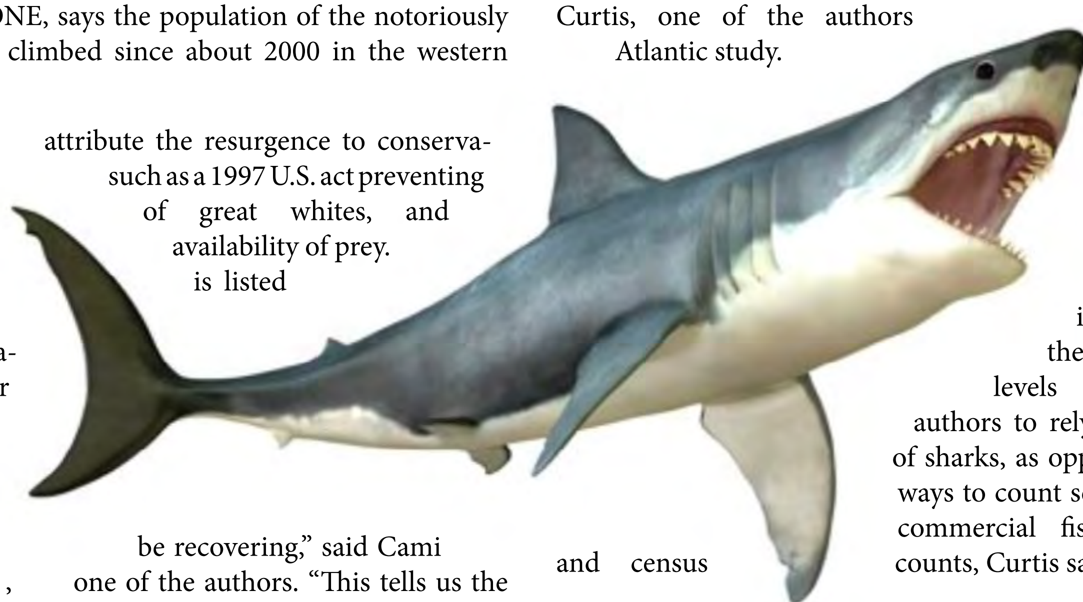
Great White Sharks Seeing Population Boom in North Atlantic

By Patrick Whittle, The Associated Press

PORTLAND, MAINE—A report that scientists are calling one of the most comprehensive studies of great white sharks finds their numbers are surging in the ocean off the Eastern U.S. and Canada after decades of decline.

The study by scientists from the National Oceanic and Atmospheric Administration, published this month in the journal PLOS ONE, says the population of the notoriously elusive fish has climbed since about 2000 in the western North Atlantic.

The scientists attribute the resurgence to conservation efforts, such as a 1997 U.S. act preventing the hunting of great whites, and greater availability of prey. The species is listed as vulnerable by the International Union for Conservation of Nature.



"The species appears to be recovering," said Cami McCandless, one of the authors. "This tells us the management tools appear to be working."

Great whites owe much of their fearsome reputation to the movie *Jaws*, which was released 39 years ago Friday. But confrontations are rare, with only 106 unprovoked white shark attacks — 13 of them fatal — in U.S. waters since 1916, according to data provided by the University of Florida.

They are, though, ecologically critical. They are apex predators — those at the top of the food chain — and help control the populations of other species. That would include the grey seal, whose growing colonies off Massachusetts have provided food.

You might be interested in

"You should be concerned for a good reason," said James Sulikowski, a professor of marine science at the University of New England in Portland, who was not involved in the study but noted it could help better target future conservation efforts for great whites. "We need these sharks in our waters."

A separate study published in PLOS ONE this month suggested that great whites — also known just as white sharks — are also returning to abundance in the eastern north Pacific Ocean.

"There's this general pattern of where the white sharks are protected, they seem to recover," said Tobey H. Curtis, one of the authors of the Atlantic study.

The elusive nature of white sharks and the lack of historical data about their population levels required the authors to rely on sightings of sharks, as opposed to other ways to count sea life, such as commercial fishing surveys and census counts, Curtis said.

The research adds recent unpublished data to previously published records to establish 649 confirmed white shark sightings from 1800 to 2010. The data show that a period of decline in white shark abundance during the 1970s and 1980s has reversed, the authors said.

White shark abundance in the western North Atlantic declined by an estimated 73 per cent from the early 1960s to the 1980s, the report says. Shark abundance is now only 31 per cent down from its historical high estimate in 1961, the report states. The report does not provide a local estimate for the great white shark population, which some scientists say is between 3,000 and 5,000 animals.

The report also illuminates where people encounter white sharks — mostly between Massachusetts and New Jersey during the summer and off Florida in the winter, it says.

They also migrate based on water temperature and availability of prey, and are more common along the coast than offshore, the report states.

What Kinds of Sharks Are in the Atlantic Ocean?

By Catherine Troiano Wild Sky Media

More than 400 species of sharks swim our global waters. Many lurk the temperate and tropical zones of the Atlantic Ocean, much to the trepidation of swimmers, surfers and divers. From as far north as New Brunswick to as far south as Brazil, the Atlantic serves as permanent address for some sharks and as seasonal residence for migratory species. The diverse collection includes the world's largest, smallest, most aggressive and most placid shark species.

Supersize Sharks

The whale shark earns the title of largest fish in the world. The migratory cosmopolitan shark is native to all of the world's oceans, including the Atlantic. His spotted body can span 40 feet in length and weigh 20 tons. The gentle giant's large mouth possesses tiny teeth since he feeds primarily on small fish and plankton. Conversely, the great white shark, growing up to 20 feet in length and weighing 6,000 pounds, has 300 serrated sharp teeth rooted in his powerful jaws to accommodate hunting and feasting on a diet that includes seals and sea lions. The film "Jaws" rendered the great white shark as the most feared shark. Another Goliath found in the Atlantic is the basking shark, measuring up to 30 feet long. The basking shark swims with his mouth open to receive his standard meal of plankton.

Whale shark

Tiny and Tenacious

One of the world's smallest sharks is the spined pygmy shark. The spined pygmy thrives in deep waters of the tropical and temperate Atlantic Ocean. Measuring an average of 7 inches long, this tiny shark will fit in the palm of your hand. The predator's preferred fare includes crustaceans, squid and fish. Another small shark whose body length averages 7 inches is the dwarf lantern shark, found primarily in the Caribbean waters surrounding Columbia and Venezuela.

Dwarf lantern shark

Armed Head to Tail

The nine species of hammerhead sharks are so named for their bizarrely shaped heads whose protuberances resemble the double-ended heads of mallets, with eyes situated at the opposing ends. The hammerhead uses this unusual physique to seek out a wide range of prey to satiate his unfussy appetite — and also as leverage to hold down his victim. The shark sporting the longest tail is the thresher shark. Half of his body length, which averages 8 feet, is devoted to the upper lobe of his tail that juts behind. This tail serves to whip and stun prey, and also to corral schools of smaller fish into its waiting jaws. The geographical range of both the hammerhead and the thresher shark spans the Atlantic seas.

Thresher shark

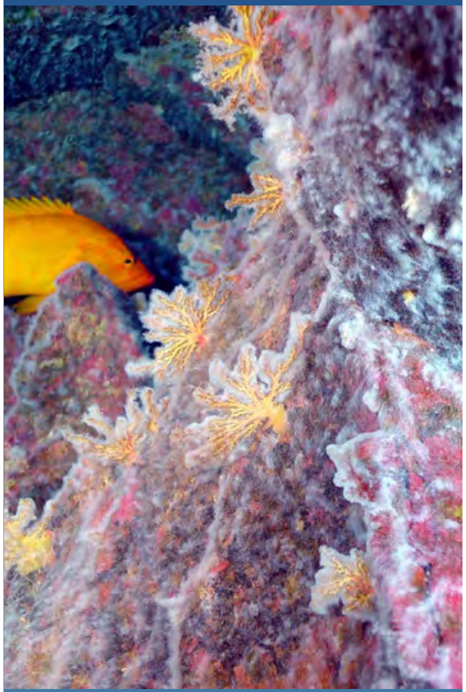
Other Atlantic Sharks

Other sharks to appear in the Atlantic include the smooth dogfish shark, the bull shark, the lemon shark, the Atlantic sharpnose shark, the nurse shark and the aggressive oceanic white-tipped shark. The most common shark of all is the piked dogfish shark, also known as the spiny dogfish shark, particularly abundant in the northern Atlantic Ocean. The shortfin mako shark is the speediest swimmer, and the blue shark holds the title of longest migration, making his vacation travels between the coast of New York and Brazil.

Oceanic white-tipped shark

OCEAN LITERACY PRINCIPLE 5:

The ocean supports a great diversity of life and ecosystems.



- Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
- There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.

2019 Awards

At the annual meeting in Woods Hole, the following awards were presented:

MME Marine Educator Award

Nicolette Pocius

Since the beginning of her studies and career, Nicolette has been devoted to marine and environmental education and research. She first became involved in the marine field while pursuing her bachelors degree at UNH, and since has given her energy and passion to promote ocean literacy as an employee and volunteer at a variety of organizations. While serving as an Americorps Fellow at the NU Marine Science Center, she mentored K-12 girls in the Beach Sisters program, delivering after school lessons and empowering teens to lead environmental service projects in their community. Now, as a science teacher in Boston at the John D. O'Bryant School for Math and Science, she brings a variety of external opportunities to her environmental science students. In her two years at the O'Bryant, she's enhanced the environmental science program with a variety of trips and initiatives including: boat field trips in partnership with the Zephyr and Vertex, a student podcasting project in partnership with NOVA and 826 Boston, and attending the High School Marine Science Symposium.

MME Annual Award of Distinction

Erin Hobbs (at Newburyport High School)

Erin has been a dedicated member of MME for many years, and has selflessly promoted marine science education both inside and outside the classroom. Her years of service to MME and the field need to be recognized.

MME Certificate of Appreciation

Bow Seat Ocean Awareness Programs

For 8+ years, Bow Seat's Ocean Awareness Contest has educated and engaged youth in ocean conservation through art-making; it is now the largest student arts and ocean advocacy competition in the world and includes visual art, writing, music, and film. 10,000 teens from 78 countries and 50 U.S. states have participated; they have awarded $300,000 in scholarships to help advance their talents and passion for the ocean. The Contest helps to strengthen 21st Century skills such as communication, critical thinking, and global awareness: 70% of students report that their participation increased their knowledge of ocean issues, and 67% report that it impacted their worldview and behavior. 86% report that creating something helped them personally connect with conservation topics. It is because of this and more that we want to present Bow Seat Awareness Programs with the MME Certificate of Appreciation.

White Shark Study

continued from page 3

research surveys, commercial and recreational fishermen, collaborating scientists, newspaper articles, personal communications, and the scientific literature and references therein. Due to species misreporting problems in the pelagic longline fishery logbook records from this fishery were considered unreliable and excluded. The data in each record typically included date, location, measured or estimated shark total length (TL), and capture gear (unless a visual observation). Lengths estimated at greater than 6 m were considered unreliable. Where lengths were reported in fork length, conversion to TL was performed using the formula in Kohler et al.. Based on published length-at-age and length-at-maturity estimates, sharks were classified as neonate (<1.5 m TL), young-of-the-year (YOY, <1.75 m TL), juvenile (1.75–3.79 and 1.75–4.5 m TL for males and females, respectively), or mature (>3.79 and >4.5 m TL for males and females, respectively). Some records had more complete data including shark weight, sex, stomach contents, photographs, water temperature, depth, or other observations. All records were given a subjective reliability ranking of A, B, C, or F similar to that described by Casey and Pratt and Skomal et al.. Records receiving a low ranking of C or F, in which the identification of the white shark seemed suspect, could not be corroborated, and/or lacked photographic evidence, were excluded from the analysis.

Distribution analysis

All records were analyzed with reference to spatial and temporal patterns of presence, as well as bottom depth and sea surface temperature (SST), when recorded. If not reported, white shark sighting locations (latitude and longitude) were assigned where possible. Data were plotted using Geographic Information System (GIS) software (ArcGIS v. 10.0, ESRI, Redlands, California). Bottom depth was subsequently assigned to each observation by matching the position to ETOPO1 Ocean Relief Model bathymetry in ArcGIS. To investigate seasonal changes in distribution, year was divided into four seasons: winter (January through March), spring (April through June), summer (July through September), and fall (October through December). Due to the inherent limitations of using presence-only information where observation effort and detectability are unknown, raw positions were simply mapped in their corresponding season, and no quantitative species distribution models were applied. In order to visualize shark distribution relative to typical SST conditions in the region, seasonal shark positions were overlaid on satellite-based 4 km Advanced Very High Resolution Radiometer (AVHRR) Pathfinder v.5.0 Seasonal Climatologies, averaged from 1985–2001 (National Oceanographic Data Center/ University of Miami).

Trends in abundance

Multiple historic and current data sources were examined for the presence of white sharks. Of those examined, we determined that only four data sources contained adequate information to estimate white shark trends in abundance for the NWA. Longline catch data were obtained from two sources: fishery-independent longline surveys conducted by the NMFS Northeast Fisheries Science Center (NEFSC) and its predecessor agencies between 1961 and 2009 and the observer program of the directed shark bottom longline fishery from 1994–2010. Data collected by the NMFS NEFSC at five recreational fishing tournaments from 1965 to 1996 (white sharks were listed as a NMFS prohibited species in 1997) were also used in this study. The tournaments were based out of New York (Bayshore Mako Tournament, Montauk Marine Basin Shark Tag Tournament, and Freeport Hudson Anglers, Inc. Shark Tournament) and New Jersey (Jersey Coast Shark Anglers Invitational Shark Tournament and South Jersey Shark Tournament). The final data source included sightings and capture records of white sharks in the NWA from 1800–2010, excluding records from the previous three time series, recent directed sightings effort, and accounting for historical directed effort leading up to and directly following the publication of the first comprehensive NWA white shark distribution paper. Historical directed sightings effort was removed from the sightings time series during the late 1970s through the1980s based on the original datasheet notations and knowledge of the persons collecting the data during that time, resulting in an 80% reduction in these sightings records (Figure S1). Following initial analyses of the sightings data, additional sightings records in the vicinity of Monomoy Island, Massachusetts were removed in recent years for trend comparisons with respect to the increase in sightings near a growing population of gray seals (*Halichoerus grypus*) in that area [14].

Due to excess zero observations in the observer data, the fishery-independent longline surveys, and the tournament data, we used a mixture of a Bernoulli distribution (with a point mass of one at zero) for presence/absence data and a Poisson distribution for count data (including zeros) in a zero-inflated Poisson (ZIP) mixture model [40]–[41] to develop standardized indices of abundance. A number of parameters were considered as potential covariates affecting the presence/ absence of white sharks and/or the white shark catch per set or tournament. For the NEFSC longline surveys, the variables available for consideration were year, season, depth, SST (<10°C, 10–14°C, 15–19°C, 20–24°C, >25°C), latitude, target (coastal shark, pelagic shark, pelagic inshore), bait type (teleost, elasmobranch, mixed), gear fishing on the bottom or up in the water column, leader type (wire, monofilament, mixed), hook number, and soak time. Variables available for the NEFSC tournament database were year, tournament, number of boats, number of days fished, and area (NY, NJ). For the observer program, the variables available for consideration were year, season, time of day, depth, area (Gulf of Mexico, southern Atlantic), hook type (small, medium, large, other), bait type (clupeid, elasmobranch, teleost, tuna, other), hook number, and research fishery participation (Amendment 2 to the 2006 Consolidated Highly Migratory Species Fishery Management Plan established a scientific research fishery in 2008 to gather information on *Carcharhinus plumbeus*). Stepwise forward model selection was used to determine which variables to retain in all final models based on the Akaike information criterion (AIC) and given a likelihood ratio test between the chosen model and the null model (intercept only) produced a test statistic value close to zero (≤0.01). All models retained "year" in order to develop annual indices of abundance. Residual plots were used to determine the adequacy of model fits.

These standardized indices of abundance were then analyzed using a hierarchical framework to estimate a single time series of relative abundance. This approach allows for the combination of multiple time series with differing lengths that do not all overlap in time. The hierarchical approach developed by Conn assumes that each index is measuring relative abundance and is subject to both process error and sampling error, the latter of which is presumably captured by the standardization process used to develop the indices of abundance. The indices (standardized to their means) and coefficients of variation were used in the hierarchical analysis to estimate individual index process error, assuming a lognormal error structure, and a hierarchical index of abundance. The hierarchical analysis was conducted in a Bayesian framework using the same set of prior distributions as described by Conn and used for other shark species for stock assessment purposes.

Annual white shark sightings were modeled using the approach developed by McPherson and Myers to examine population trends from observational data. This method extracts the abundance trend in relative terms by fitting a series of generalized linear models to the difference in the count data between two points in time (difference between the most recent time point and any reference date) using a Poisson distribution and guards against sensitivity to unusually high or low counts by varying the reference period used to derive the count differences. The estimated trend in relative abundance can then be viewed by plotting the magnitude of change in the number of reported sightings by year in log-space. Resulting values larger than 1 suggest an overall declining trend in abundance, values of 1 suggest a stable population, and values less than 1 suggest an overall increasing trend in abundance. This approach was used on the sightings data for multiple time frames. The sightings data were analyzed given any reference year from 1800 to 2008, 1950 to 2008, 1960 to 1986, and 1990 to 2008. Sensitivity analyses were conducted assuming changes in observation effort had either increased or decreased by 25% and 50%. All analyses were conducted using the R programming environment.

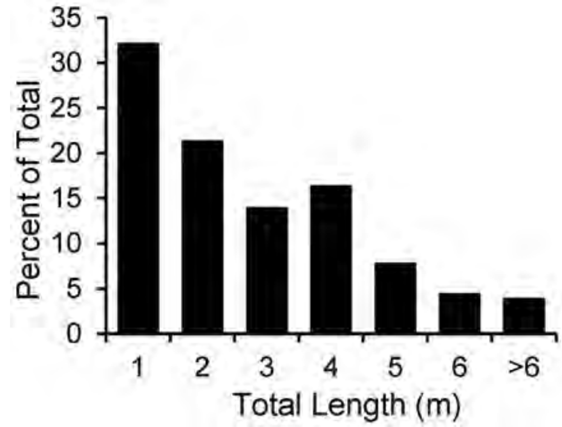


Figure 1. White shark lengths.
Length frequency of white sharks from the western North Atlantic (N = 538). These data include lengths from accurately measured specimens (N=279), as well as estimated lengths, rounded down to the nearest m.

Results

We compiled a total of 649 verified white shark records from the NWA during the period 1800–2010. While the records date as far back as 1800, 94% occurred since 1950. Of these, 596 records had sufficient data (i.e., date and location) for seasonal distribution analysis and 433 were included in relative abundance time series runs (excluding directed effort, N=200, and sightings with no associated year, N=5).

Sex of the shark was confirmed in 297 records and included 148 males and 149 females. Sharks that were accurately measured (N=279) ranged in length from 1.22–5.63 m TL. An additional 259 records included estimated lengths, which we rounded down to the nearest m TL (1–9 m TL) (Figure 1). The records collectively included 124 YOY, 310 juveniles, and 104 mature sharks. While some white sharks were reported at estimated lengths exceeding 9 m, these

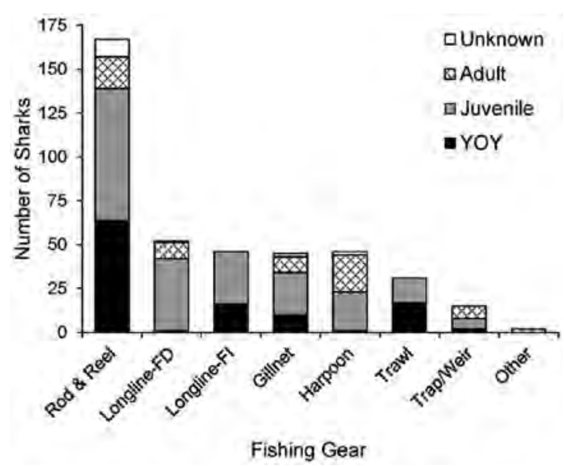


Figure 2. White shark gear interactions.
Reported fishery-dependent and fishery-independent gear interactions with white sharks by life stage in the NWA, 1800–2009 (N=390).

estimations were considered unreliable. The largest shark considered accurately measured was a female specimen landed on Prince Edward Island, Canada in August 1983, which measured 5.26 m fork length (5.63 m TL).

Gear interactions

Confirmed gear interactions represented 66% (404) of the white shark records compiled, including both targeted and incidental catches. Forty-one percent of these records were derived from recreational rod and reel fishing (Figure 2). Amongst the remaining gear types, white sharks were most frequently captured by fishery – dependent (13%) and independent (11%) – longline gear (bottom and pelagic), harpoon (11%), and gillnet (11%, sink and drift), with fewer numbers caught in trawls (8%) and fish weirs/traps (4%) (Figure 2). The practice of harpooning large white sharks, responsible for the majority (33%) of mature white shark captures, was more prevalent prior to 1980, and has been uncommon since 1997 when white sharks were prohibited from commercial and recreational harvest. Since 1985, fishery-dependent longline gear (40%) dominated reported white shark captures with rod and reel captures dropping to 35%. Within commercial fisheries (1985–2009), longline (60%) and gillnet (17%) have been the primary sources of incidental captures reported, and these gears predominantly catch immature sharks (Figure 2). Recreational rod and reel fishing accounted for 28% of the mature white sharks landed, with 72% of these captured between 1960 and 1990. Most of these landings occurred between Long Island, New York, and Massachusetts. However, juvenile white sharks (including YOY) were also frequently caught by rod and reel fishermen (Figure 2).

Seasonal distribution

The range of white shark occurrence extended from the north coast of Newfoundland (51° N) to as far south as the British Virgin Islands (18° N), as far east as the Grand Banks (50° W) and Bermuda (65° W), to as far west as

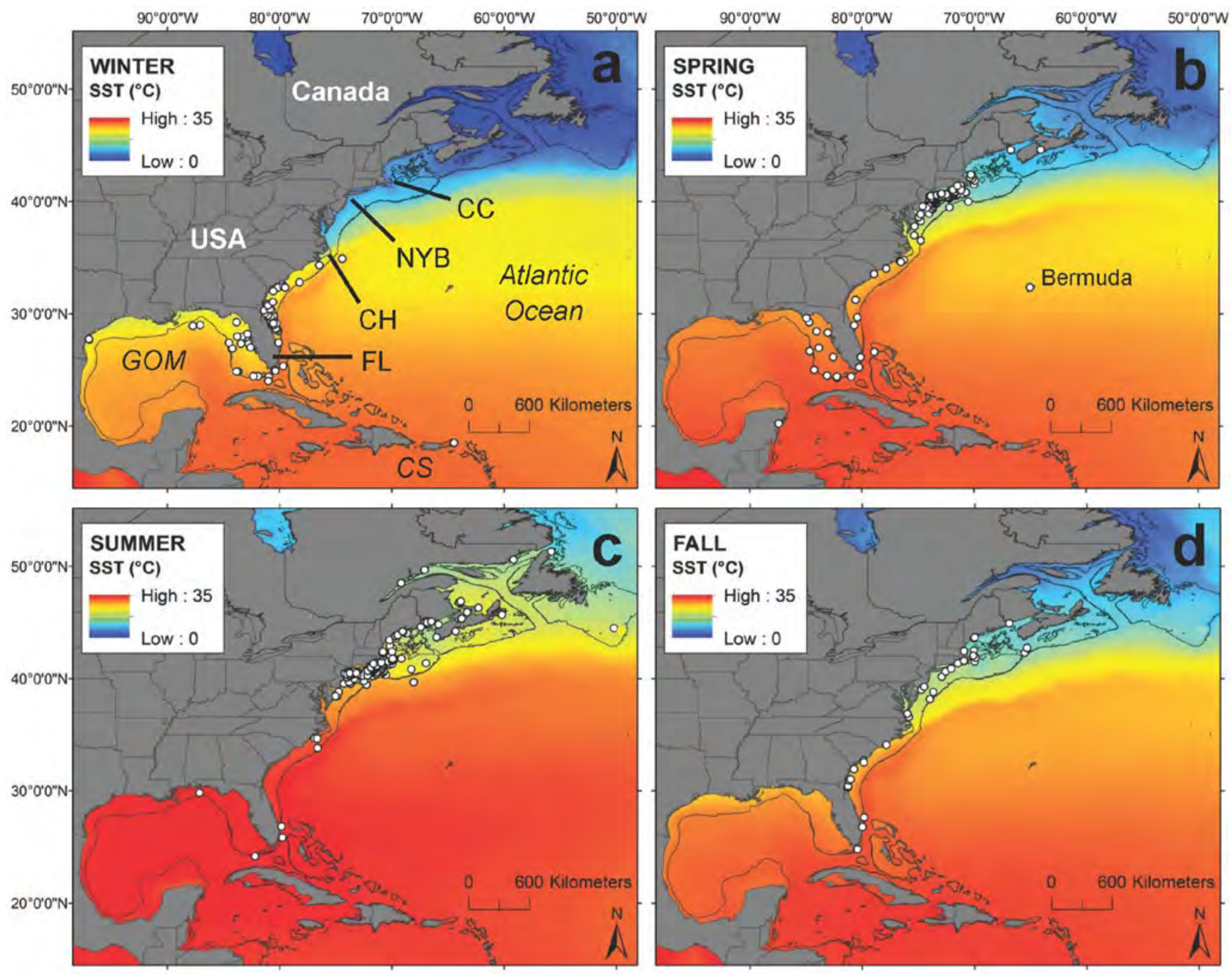


Figure 3. White shark seasonal distribution.

Distribution of white shark presence records (white circles) in the NWA during (a) winter, (b) spring, (c) summer, and (d) fall. Positions are overlaid on seasonal average SST conditions (1985–2001). The 200 m bathymetric contour is displayed to delineate the edge of the continental shelf. CC = Cape Cod, NYB = New York Bight, CH = Cape Hatteras, FL = Florida, GOM = Gulf of Mexico, and CS = Caribbean Sea.

the coast of Texas in the Gulf of Mexico (97° W) (Figure 3). While this overall distribution is quite broad, 90% of white sharks occurred along the US coast between 22° 00' and 45° 30' N (100% YOY, 86% juvenile, 89% mature). The center of distribution was in southern New England and the Mid-Atlantic Bight (between 35° 00' and 42° 00' N), where 66% of white sharks occurred (97% YOY, 54% juvenile, 70% mature).

White sharks of all size/age classes were present in continental shelf waters throughout the year. However, there were considerable differences in distribution across seasons (Figure 3). During winter months, white sharks (2% YOY, 75% juvenile, 27% mature) were primarily distributed off the southeastern US and in the Gulf of Mexico. Only one YOY white shark was captured during the winter months. This shark measured 1.64 m TL and was captured off North Carolina in January 1996. The median latitude of occurrence during winter months ranged from ~28–31° N (Figure 4). No white sharks were reported north of Cape Hatteras (~35° N) during winter.. Focal areas of winter occurrence were identified off the northeast coast of Florida (smaller juvenile through mature-sized individuals), off the Florida Keys (larger juvenile and mature sharks), and offshore of Tampa Bay (smaller juvenile through mature sharks) in the eastern Gulf of Mexico.

During spring months, there was a clear expansion northward (Figure 4). White sharks (28% YOY, 50% juvenile, 22% mature) occurred widely along the coast, mostly between the eastern Gulf of Mexico and the New York Bight (waters off the US Atlantic coast from Cape May Inlet in New Jersey to Montauk Point in Long Island, New York, Median latitude of occurrence shifted dramatically across spring months, from 28° N in April to 40° N in June (Figure 4). The northernmost occurrences during this period typically occurred in late spring (May and June) (Figure 4) and the majority were large juvenile and mature sharks.

By summer, white sharks (23% YOY, 47% juvenile, 30% mature) appeared largely absent from southern coastal waters, occurring primarily in the Mid-Atlantic Bight, New England, and Canadian waters. Only a few white sharks (mature) have been reported from south of Cape Hatteras during summer. Most records were centered from the New York Bight eastward and north to Cape Cod. White sharks, predominately large juvenile and mature individuals, appear to reach the most northern portions of their NWA range (Newfoundland, Gulf of St. Lawrence) during August (Figure 4) but the median latitude of occurrence for all life stages remains around 40–41° N throughout the summer (Figure 4).

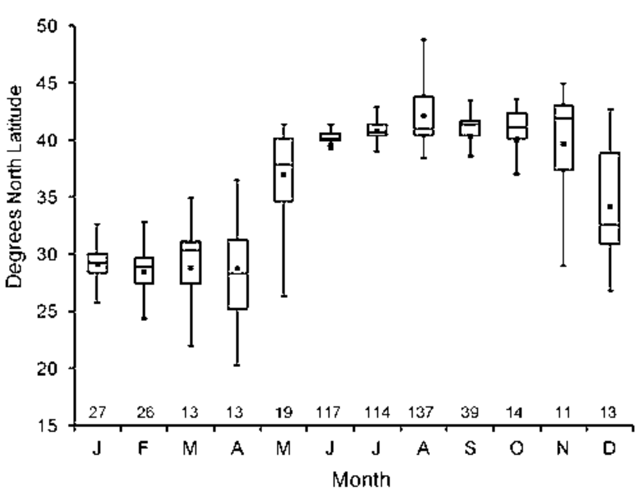


Figure 4. White shark monthly distribution.
Box plots of latitudinal distribution of white shark presence by month in the NWA. The sample size in each month is given above the x-axis.

YOY sharks were most frequently encountered during summer between the central coast of New Jersey and Massachusetts Bay. However, most YOY shark observations (64%) were concentrated in the New York Bight between Great Bay, New Jersey, and Shinnecock Inlet, Long Island, New York. Neonate-sized white sharks (N=46) were documented in this area between June and October (85% in June-August). Mature-sized female white sharks were also documented from this region during summer months, but no gravid or post-partum females were examined.

White sharks (15% YOY, 64% juvenile, 21% mature) remained in northern latitudes into the fall, but appeared to begin a southward transition in November and December (Figure 4). Similar to spring months, white shark occurrence was broadly distributed along the coast between New England and the east coast of Florida. The largest shift in median latitude occurred between November (42° N) and December (34° N) (Figure 4).

Habitat Use

While environmental observations were limited throughout this data set, some patterns of habitat use were identified. Depth distribution data (N=564) indicated that white sharks were predominantly encountered over continental shelf waters (200 m, Figure 3). Over 92% of observations occurred in waters 100 m deep, and the median reported depth at occurrence was 30 m (mean ±1 SD =69±235 m). Only 23 observations occurred in deeper waters off the continental shelf, however, many of these were still relatively close to shore (e.g., off the Florida Keys, Figure 3). For YOY (N=102), juvenile (N=265), and mature (N=125) sharks, the median depth at occurrence was 32 m (mean ±1 SD =32±19 m), 26 m (mean ±1 SD =45±74 m), and 50 m (mean ±1 SD =89±190 m), respectively; indicating a potential increase in the use of deeper waters by white sharks with increased size/age.

White sharks were captured in SSTs (N =124) of 9–28°C (mean ±1 SD =18.3±3.5°C). For YOY (N=26), juvenile (N=68), and mature (N=21)

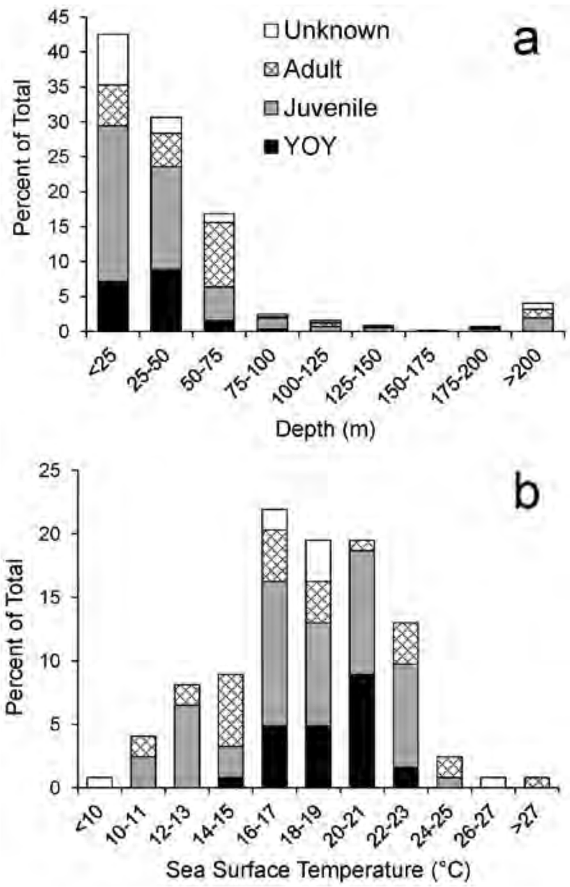


Figure 5. White shark habitat use.
Distribution of (a) bottom depths (N=564) and (b) SST (N=124) associated with NWA white shark captures/sightings.

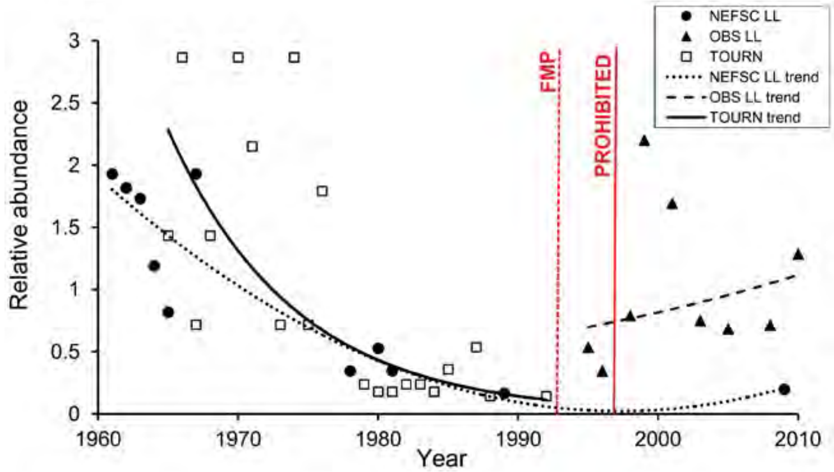


Figure 6. White shark relative abundance.
White shark indices of abundance (index/mean) standardized using a zero-inflated Poisson model plotted by year for three time series: NEFSC LL = Northeast Fisheries Science Center fishery-independent longline surveys, TOURN = NEFSC tournament database, and OBS LL = observer program of the directed shark longline fishery. Trend lines are best fit regression models of the standardized data (second order polynomial for NEFSC LL and exponential for TOURN and OBS), using R^2 values and considering the biology of the white shark. The dashed red line indicates the year of the first fishery management plan (FMP) for Atlantic sharks in 1993 and the solid red line indicates the year that white sharks were listed as a NMFS prohibited species in 1997.

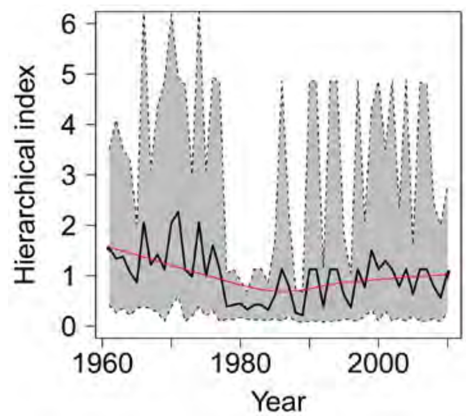


Figure 7. White shark relative abundance trend.
Time series of white shark relative abundance in the NWA as estimated from hierarchical analysis. The continuous black line gives the posterior mean, and the shaded area represents a 95% credible interval about the time series. The red line is the estimated trend based on locally weighted polynomial regression using the LOWESS smoother.

sharks, the median reported SST at occurrence was 19.5°C (mean ±1 SD =19.0±1.9°C), 18°C (mean ±1 SD =18.1±3.5°C), and 16°C (mean ±1 SD =17.7±4.6°C), respectively. Over 80% of observations with temperature information were between 14 and 23°C Additionally, analysis of the NEFSC longline survey database suggested a preference for a similar SST range (see Trends in Abundance section).

Trends in Abundance

The best fit model for the NEFSC longline surveys indicated that both the presence/absence and number of sharks per set were primarily influenced by soak time. There was a higher likelihood of catch with longer soak times, but within the positive catch sets, the longest soak times produced fewer white sharks, possibly due to bite offs (observed severed leaders) and/or predation. The presence/absence of white sharks in the NEFSC longline surveys was also influenced by SST with a higher likelihood of catch in the 15–19°C and 20–24°C temperature categories. Depth also influenced catch per set with higher catch rates in shallower depths. The presence/absence of a white shark at sampled tournaments was influenced by tournament location, with a higher likelihood of catching a white shark during one of the tournaments based out of New Jersey during the reported sampling time frame. For the observer program, the presence/absence of white sharks was primarily influenced by area fished and effort (number of hooks); catch per set was also influenced by area fished as well as season (highest catches off the Atlantic coast of Florida during the winter).

Both standardized indices of relative abundance for the NEFSC longline surveys and the tournament data show decreasing estimates over time until the end of tournament time series, when white sharks were prohibited. Then the NEFSC longline index appears to increase based on best fit regression models of the data (Figure 6) The second order polynomial trend line estimated for this time series fits

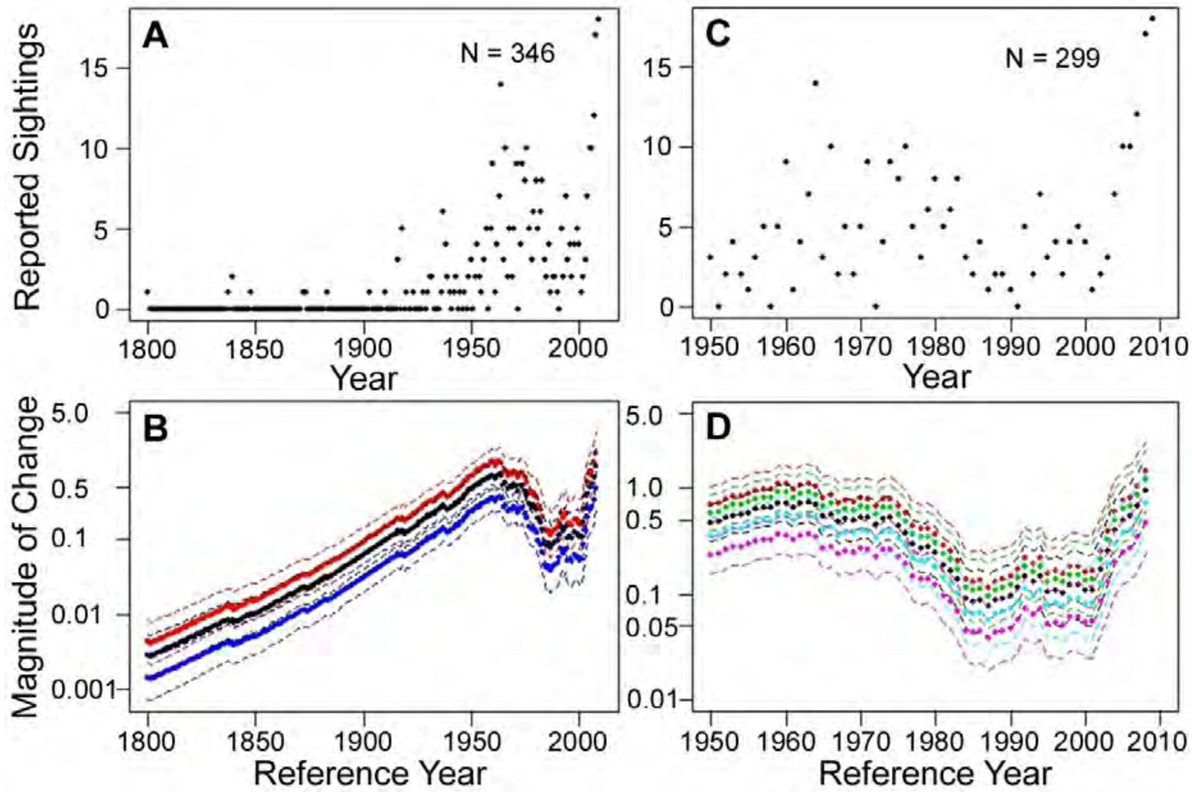


Figure 8. Time series of white shark sightings.
(a) Number of annual white shark sightings reported in the NWA from 1800 to 2009. (b) Estimates of relative change in abundance (filled circles) with 95% credible intervals (dashed lines) for any reference year between 1800 and 2008 assuming no change (black plot), a 50% increase (red plot), and a 50% decrease in observation effort. (c) Number of annual white shark sightings reported in the NWA from 1950 to 2009. (d) Estimates of relative change in abundance (filled circles) with 95% credible intervals (dashed lines) for any reference year between 1950 and 2009 assuming no change in observation effort (black plot), a 25% and 50% increase in observation effort (green and red plots, respectively), and a 25% and 50% decrease in observation effort (blue and purple plots, respectively).

without knowledge of the survey data in that the ZIP model could not provide estimates for several zero catch years during the mid to late 1990s and into the early 2000s. The observer index, which started after the implementation of the first shark fishery management plan in 1993, has an overall increasing trend in relative abundance throughout the time series, despite the large peak in the early 2000s, which the standardization process could not account for (Figure 6).

The hierarchical trend combining all three indices, although slightly masked by the large credible intervals for the index, shows historically higher abundances during the 1960s and into the mid-1970s with a declining trend into the late 1980s and then begins a gradual increasing trend through the remainder of the time series (Figure 7). During the mid-1970s and throughout the 1980s, white shark relative abundance had declined between 27 and 86%, with a median value of 73%. The most recent year in the time series (2010) shows only a 31% decline in white shark abundance from its historical abundance estimate in 1961. Estimates of process error show the three indices performed reasonably well for white shark abundance and values were similar across indices (indices process standard deviation estimates ranged from 0.405–0.457).

Excluding the time series analyzed separately and directed effort, a total of 346 white sharks were sighted between 1800 and 2009. with over 86% (299) of the sightings occurring between 1950 and 2009 (Figure 8). Under the assumption of no change in observational effort, the sightings model estimated that there was an overall increasing trend (all estimated values less than 1) in the NWA white shark population since the 1800s, most notably during the beginning of the time series through the 1950s and during more recent years. A closer look at the relative abundance trend starting in the 1950s, reveals that even though the change in magnitude from any reference year between 1950 and 2008 to the terminal year in 2009 results in an increase in relative abundance (magnitude of change 1), there still appears to be a declining trend during the 1970s into the mid 1980s. Sensitivity analyses estimating 25 and 50% increases and decreases in observation effort clearly increases the uncertainty surrounding the estimates of change in abundance, but the overall trend remains the same. Analysis of the sightings data with a terminal year of 1987 reveals an estimated 2–4-fold (median

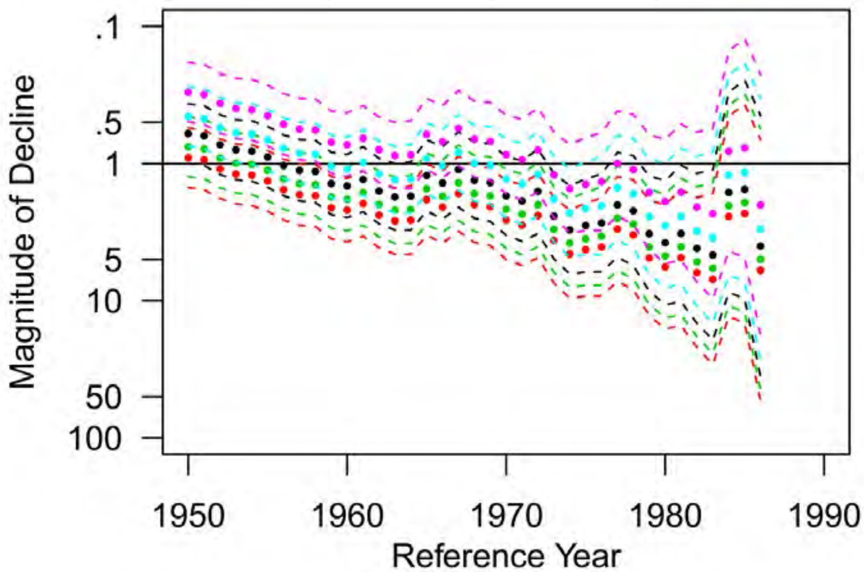


Figure 9. White shark relative decline in abundance.
Estimates of relative decline in abundance (filled circles) with 95% credible intervals (dashed lines) for any reference year between 1960 and 1986 assuming no change in observation effort (black plot), a 25% and 50% increase in observation effort (green and red plots, respectively), and a 25% and 50% decrease in observation effort (blue and purple plots, respectively). Note that the scale for the y-axis has been reversed when compared to Figure 8 to visualize the declining trend in abundance during this time period.

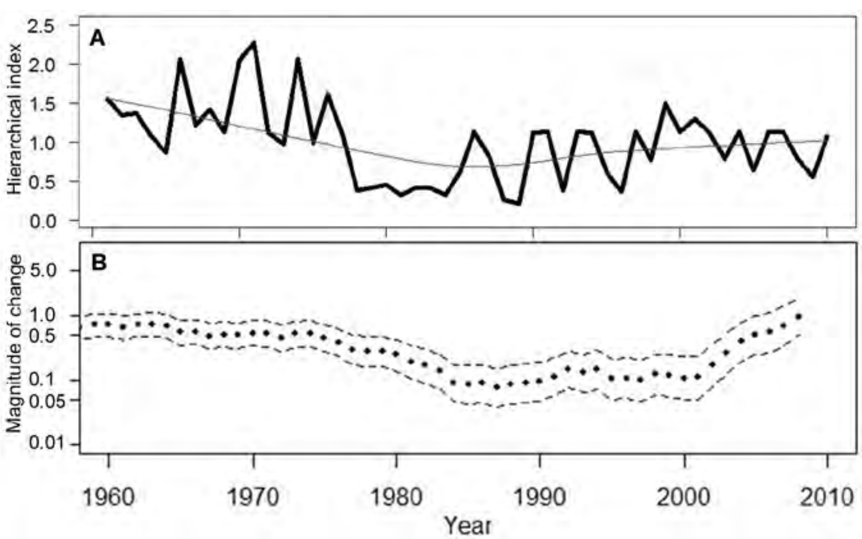


Figure 10. Trend comparison of white shark relative abundance.
Estimates of relative change in abundance (filled circles) with 95% credible intervals (dashed lines) for any reference year between 1990 and 2008 assuming no change in observation effort (black plot), a 25% and 50% increase in observation effort (green and red plots, respectively), and a 25% and 50% decrease in observation effort (blue and purple plots, respectively) for the original sightings time series from 1990 to 2009 (a) and the time series with sightings that occurred near Monomoy Island during that time frame removed (b).

estimate =2.71, 63% decline) decrease in the population since any reference year between 1970 and 1986 (Figure 9). If we reduce the observational effort by 25% and 50%, it reduces the estimated decline during the 1970s into the mid 1980s to 51% and 26%, respectively (median estimates =2.02 and 1.36, respectively) (Figure 10). A 98% reduction in observational effort is needed to avoid a decline in abundance during that time frame (model estimates and confidence bounds consistently drop below 1). During the 1990s, the relative abundance trend appears to stabilize and then begins an increasing trend during the 2000s until the end of the time series. This overall increasing trend in relative abundance during the end of the time series is retained when assuming 25 and 50% increases and decreases in observation effort.

Discussion

This study represents the most comprehensive synthesis of data on NWA white sharks to date, and significantly updates previous reviews. In general, the white shark remains an uncommon and sparsely distributed predator in the NWA. However, by combining over two centuries worth of observations the results have provided new insights into population and distribution trends along the east coast of North America.

Seasonal Distribution and Habitat

The use of presence-only data for describing species distributions has inherent limitations. Results may be biased by spatial and temporal variability in observation effort, detectability, and catchability. However, presence records from captures and sightings are often the best source of baseline information on comparatively uncommon marine species like the white shark. Since the majority of our records were derived from fisheries interactions, patterns in fishing effort and gear over space and time should partially account for the patterns we have described. One important bias is that the occurrence of adult white sharks in our dataset is likely underestimated due to the fact that these large individuals can more easily escape entanglements/hooking in fishing gear.

Since most fishing effort and boating activity in the NWA occurs over continental shelf waters, encounter rates with white sharks may be biased toward the coasts. Therefore, white shark occurrence in offshore waters may be underrepresented in this analysis. The only fishery likely to encounter white sharks in offshore waters is the pelagic longline fishery, which targets tunas and swordfish, but regularly incidentally captures pelagic shark species including silky (*Carcharhinus falciformis*), dusky (*C. obscurus*), oceanic whitetip (*C. longimanus*), and blue (*Prionace glauca*) sharks. However, the occurrence of white sharks in this offshore fishery appears to be extremely low. We agree with the assertions of Burgess et al. that the 6,087 white sharks reported in pelagic longline fishery logbooks according to Baum et al. were probably not in fact *Carcharodon carcharias*, and these records should not be used to infer distribution or abundance patterns for this species. Given the occasional reports of white sharks from offshore waters beyond the continental shelf, including their documented occurrence in Bermuda waters and recent satellite tracking data (GBS, unpublished data), further observations, stable isotope analyses, and/or advanced technology tagging studies are needed to provide a greater understanding of their use of offshore habitats in this region.

In the absence of seasonal shifts in shark distribution, fisheries would be expected to have fairly equal probability of encountering white sharks across the year throughout their range. However, this was not the case for several fisheries, as encounters were unevenly distributed across seasons. For example, despite observer coverage for the majority of the year in the shark bottom longline fishery, no white sharks were encountered during summer months off the southeast US. Likewise, catch and observer records in commercial trawl and gillnet fisheries off New England and Canada primarily documented white sharks during summer months, despite year-round fishing activity and observer coverage (NMFS Northeast Fisheries Observer Program, unpublished data). These trends appear to support the seasonal north-south distribution shift of the NWA white shark population, despite the limitations of using presence-only information. This north-in-summer, south-in-winter distributional pattern is typical of numerous temperate, coastal, migratory fishes in the northern hemisphere and white shark migrations from temperate to subtropical waters have also been documented off the west coast of the United States and Mexico and off the Pacific coasts of Australia and New Zealand.

Consistent with previous studies on white sharks temperature appears to exert a significant influence on distribution, and is likely a key migratory cue in the region. The seasonal movement of the white shark population up and down the Atlantic coast of North America, an average shift of approximately 12° of latitude (28–40° N, Figure 4 allows white sharks to remain within an apparently preferred SST range of ~14–23°C. Given their comparatively large body mass and endothermic capabilities, this relatively narrow temperature range does not define the white sharks thermal tolerance which extends from at least 3–28°C, but it does appear to largely define the bounds of their seasonal latitudinal range in this region. Therefore, while temperature may drive seasonal distribution shifts, the selection of specific summer and winter habitats is likely based upon environmental characteristics secondary to temperature (e.g., prey availability).

The relatively broad summer focal area for white sharks between the coasts of New Jersey and Massachusetts likely include important foraging areas across life stages. YOY and juvenile white sharks, which were more prevalent in the New York Bight region during summer, would have access to a wide variety of demersal and pelagic teleosts and elasmobranchs for prey.The waters less than 50 m deep on the broad continental shelf in the New York Bight area may represent primary nursery habitat for YOY white sharks. The seasonal peak in the presence of neonate-sized sharks suggests that parturition may occur near this area between May and August. White shark nursery habitat has also been identified in other regions along continents where larger expanses of shelf habitat exist.

Large white sharks (3.0 m) tend to preferentially feed upon marine mammals including pinnipeds, small cetaceans, and large whale carcasses. Since pinniped populations in the NWA have been severely depressed throughout most of the last century, confirmed predations on seals (*Phoca vitulina*, *Halichoerus grypus*) have been rare until very recently. Whale carcasses are thought to be one of the most important sources of food for large white sharks in this region. White sharks have been observed scavenging dead whales off New England and Long Island, New York on numerous occasions [24,63, 66–67, NMFS unpublished data, JKC personal observation), but they also supplement their diet with odontocete whales such as the harbor porpoise (*Phocoena phocoena*) and fishes including tunas (Thunnus spp.), sea robins (*Prionotus* spp.), menhaden (*Brevoortia tyrannus*), hakes (*Urophycis* spp.), skates (Rajidae), bluefish (*Pomatomus saltatrix*), smooth dogfish (*Mustelus canis*), and other shark species, NMFS unpublished data).

Due to the dynamic and broad distribution of prey (i.e., teleosts, marine mammals) in this region, white sharks must forage over a broad area, rather than at discrete aggregation sites like those off California, Australia, or South Africa. However, the recovery of NWA gray seal populations over the last decade and their increasing concentrations at specific sites along Cape Cod, Massachusetts, appears to be producing new localized summer feeding aggregations for white shark.

Although the summer distribution of white sharks in the NWA has been described in previous studie, there has been very limited information on the focal areas for white shark occurrence during winter months. White sharks have long been thought to be rare and occasional visitors to coastal waters off the southeast US, Gulf of Mexico, and the northern Caribbean Sea. However, the current results indicate that white sharks visit these subtropical waters on a regular basis during the winter. The most notable areas of repeated occurrence during winter months are the Atlantic shelf waters between southern Georgia and Cape Canaveral, Florida and Gulf of Mexico shelf waters west of Tampa Bay, Florida for small juvenile through mature sized individuals, and Atlantic coastal waters along the Florida Keys for larger juvenile and mature white sharks.

The reasons why white sharks are drawn to particular subtropical areas during winter months are unclear, but they likely include important foraging grounds. Analysis of white shark stomach contents from this region are extremely limited, however, documented prey items include dolphins (Delphinidae), sharks (Carcharhinidae), red drum (*Sciaenops ocellatus*), sea turtles, and squid. Authors unpublished stomach contents data). Historically, white sharks that occurred along the Florida Keys and northern Caribbean islands may have also preyed upon the now extinct Caribbean monk seal (*Monachus tropicalis*) [73]. Juvenile and adult white sharks have also been observed scavenging upon the carcasses of North Atlantic right whales (*Eubalaena glacialis*) in the waters off Georgia and northern Florida on several occasions [74]. This area is designated as critical habitat for the right whale, and includes their primary (December-March) calving grounds. White sharks are not known to actively prey upon healthy adult mysticete whales but it is possible that they are drawn to this area during the right whale calving season in order to attempt to prey upon calves, or scavenge upon occasional carcasses of adults or calves and/or whale placentas. Seasonal movement of white sharks to subtropical calving grounds of humpback whales (*Megaptera novaengliae*) has been documented in the North and South Pacific Oceans. Despite the unpredictable availability of large whale carcasses, white sharks may regularly migrate to whale aggregation areas for foraging/scavenging. The particularly high caloric value of whale blubber tissue makes it an optimal food choice to help meet the high energetic demands of the endothermic white shark.

In summary, given the available information on white shark distribution, feeding habits, and habitat use, it appears that the annual north-south distribution shift of the white shark population is driven by a combination of environmental preferences and prey availability. White sharks move into summer feeding areas off the northeast US when SST rises above approximately 14°C. They feed on a wide variety of prey over a broad area, but large white sharks have been increasingly associated with emerging gray seal colonies off Massachusetts in recent years. As temperatures decline during the fall, the shark population shifts southward, eventually reaching putative foraging grounds off Georgia and Florida. White sharks have been documented to occur on continental shelf waters throughout the year, and may migrate along the Atlantic coast rather than regularly moving into offshore pelagic waters, as they do in the eastern North Pacific. The sparse observations in Mid-Atlantic waters between Maryland and South Carolina for all life stages suggest this stretch of coast may be a migratory corridor, connecting northern and southern feeding areas. However, preliminary satellite tracking data from this region suggest that some individuals may also spend considerable amounts of time beyond the continental shelf (GBS, unpublished data). More observations, tagging, and telemetry studies are necessary to shed more light on these patterns.

Abundance Trends and the Status of NWA White Sharks

The results of our relative abundance analyses offer a more optimistic outlook for NWA white sharks than previous reports. Consistent with previous analyses, significant declines (63–73%) through the 1970s and 1980s were identified, but previously undocumented positive trends were present in available time series since the early 1990s. The hierarchical method, allowing the combination of multiple time series that did not all overlap in time, had the largest amount of uncertainty associated with its estimated trend of relative abundance. During simulation testing of the hierarchical method, Conn reported that the credible intervals for the hierarchical index were frequently wider than nominal for all simulation scenarios, suggesting that the estimation procedure was overly conservative. Although there is uncertainty in all trends used in this study, the concordance of multiple data sources in the timing of population changes lends credence to the observed patterns. The population declines of the 1970s and 1980s and the increases during the 1990s are also parsimonious with our understanding of the expansion and eventual regulation of shark fisheries during this period.

Though no real trend can be inferred, an additional source of historic and contemporary relative abundance comes from the shark bottom longline fishery off Florida. From 1935–1950, prior to widespread commercial shark fishing and purported population declines, white sharks represented approximately 1 out of every 3,704 sharks captured in this fishery. Despite some likely changes to gear and effort over time reported, white sharks represented approximately 1 out of every 3,443 sharks captured in the same fishery between 1994 and 2003. This is a remarkably small difference between observations separated by over 40 years. Though these are just two points in time, the similarity in relative occurrence may indicate that white shark abundance in this region is currently comparable to what it was in the 1930s and 1940s. Had the stock collapsed and remained at decimated levels, the relative occurrence ratio in Morgan et al. would likely have been significantly lower than that reported by Springer.

There is evidence suggestive of recent increases in white shark abundance in other regions, similar to what is documented here for the NWA. Catch per unit effort from protective beach nets show an apparent increasing trend in relative abundance for white sharks during the 2000s in South Africa [and during the mid 1990s through the 2000s in New Zealand. Catches of white sharks from southern California fisheries have also increased in recent years despite significant reductions in fishing effort. Similar to the US Atlantic, all of these regions have legally protected white sharks from harvest since the 1990s. Though data remain comparatively sparse for white sharks, and significant uncertainty remains in all abundance trend estimates in this study), there is growing evidence that legal protections for white sharks in the NWA and elsewhere around the world have been effective. Population declines appear to have been halted and populations may now be stabilized or growing in several regions. However, given the white sharks inherent sensitivity to exploitation and low productivity fishery bycatch mortality remains a concern to the long-term sustainability of their populations.

Despite some recent progress in our understanding of the biology of white sharks in the NWA there are still considerable knowledge gaps in this region compared to other areas. Significant questions remain on life history, population structure and size, behavior, habitat preferences, feeding habits, movements, and migration. Other than the possible presence of a summer nursery area in the New York Bight, virtually nothing is known about the location and timing of mating or parturition. It is not known if the timing and extent of white shark migrations in the NWA are similar to those described in recent satellite tracking studies in the Pacific and Indian Oceans. Further research will help fill in many of these information gaps, and continued compilation of opportunistic sightings, fishery captures, and examination of occasional specimens will, over time, help to further expand our knowledge and improve conservation strategies.

NOAA Ocean Facts

Despite their scary reputation, sharks rarely ever attack humans and would much rather feed on fish and marine mammals.

Only about a dozen of the more than 300 species of sharks have been involved in attacks on humans. Sharks evolved millions of years before humans existed and therefore humans are not part of their normal diets. Sharks are opportunistic feeders, but most sharks primarily feed on smaller fish and invertebrates. Some of the larger shark species prey on seals, sea lions, and other marine mammals.

Sharks have been known to attack humans when they are confused or curious. If a shark sees a human splashing in the water, it may try to investigate, leading to an accidental attack. Still, sharks have more to fear from humans than we do of them. Humans hunt sharks for their meat, internal organs, and skin in order to make products such as shark fin soup, lubricants, and leather.

Sharks are a valuable part of marine ecosystems, but overfishing threatens some shark populations. NOAA Fisheries conducts research on shark habitats, migratory patterns, and population change in order to understand how to best protect and maintain a stable shark population.

Scientists discover different kind of killer whale off Chile

Source NZ Herald | By Seth Borenstein

For decades, there were tales from fishermen and tourists, even lots of photos, of a mysterious killer whale that just didn't look like all the others, but scientists had never seen one.

Now they have.

An international team of researchers says they found a couple dozen of these distinctly different orcas roaming in the oceans off southern Chile in January. Scientists are waiting for DNA tests from a tissue sample but think it may be a distinct species.

The National Oceanic and Atmospheric Administration felt confident enough to trumpet the discovery of the long rumored killer whale on Thursday. Some outside experts were more cautious, acknowledging the whales are different, but saying they'd wait for the test results to answer the species question.

"This is the most different looking killer whale I've ever seen," said Robert Pitman, a NOAA marine ecologist in San Diego. He was part of the team that spotted the orcas off Cape Horn at the tip of South America.

How different? The whale's signature large white eye patch is tiny on these new guys, barely noticeable. Their heads are a bit more rounded and less sleek than normal killer whales and their dorsal fins are narrower and pointed.

This combination of photos provided by Paul Tixier and NOAA shows a Type D killer whale, top, and a more common killer whale. Photo / via AP

They likely mostly eat fish, not marine mammals like seals, as other killer whales do, Pitman said. Fishermen have complained about how good they are at poaching off fishing lines, snatching 200-pound fish away.

Pitman said they are so different they probably can't breed with other killer whales and are likely a new species. At 6 to 7.5 metres, they are slightly smaller than most killer whales. In the Southern Hemisphere, killer whales are considered all one species, classified in types A through C. This one is called type D or subantarctic killer whales.

Michael McGowen, marine mammal curator at the Smithsonian, said calling it a new species without genetic data may be premature. Still, he said, "I think it's pretty remarkable that there are still many things out there in the ocean like a huge killer whale that we don't know about."

Scientists have heard about these distinctive whales ever since a mass stranding in New Zealand in 1955. Scientists initially thought it could be one family of killer whales that had a specific mutation, but the January discovery and all the photos in between point to a different type, Pitman said.

He said they are hard to find because they live far south and away from shore, unlike most killer whales.

"The type D killer whale lives in the most inhospitable waters on the planet. It's a good place to hide."

Pitman got interested in this mysterious killer whale when he was shown a photograph in 2005. When he and others decided to go find them, they followed the advice and directions of South American fishermen, who had seen the whales poaching their fish.

After weeks of waiting, about 25 of the whales came up to the scientist's boat, looking like they expected to be fed. Equipment problems prevented the scientists from recording enough of the whale songs, but they used a crossbow to get a tissue sample. Pitman said the whales are so big and their skin so tough that it didn't hurt them, saying the arrow "is like a soda straw bouncing off a truck tire."

Pitman said he'll never forget January 21 when he finally saw his first and then a bunch of the type D orcas.

"For 14 years I was looking for these guys. I finally got to see them," Pitman said.

He acknowledged that he did sound like the revenge-seeking captain in the classic novel "Moby-Dick."

"I guess I know how Ahab felt, but for a good reason," Pitman said.

Young people like the plaintiffs are uniquely vulnerable to the effects of global warming.

By Richard Carmona and David Satcher
Drs. Carmona and Satcher are former surgeons general of the United States.

Kelsey Juliana, the named plaintiff in a climate change lawsuit brought by 21 young people against the federal government, greeted supporters in Eugene, Ore., last fall. Credit Andy Nelson/The Register-Guard, via Associated Press

June 3, 2019 In 2015, 21 young people from around the country and various walks of life sued the federal government over its role in creating a "dangerous climate system" that violates their right to an environment "capable of sustaining human life." The Trump administration has sought to have the case dismissed, and on Tuesday, a three-judge panel of the United States Circuit Court of Appeals for the Ninth Circuit is scheduled to take up the question of whether it can proceed.

As former surgeons general of the United States, we were responsible for providing Americans with the best scientific information on how to improve their health and protect against illness and injury. Because climate change represents a profound threat to the public's well-being, we support the Juliana 21, named after the lead plaintiff, and believe their case should go to trial.

Even in this time of deep social and political division, individuals of good will can agree on certain fundamental premises. Investment in public health is one of them. The country has eliminated polio, reduced cancer death rates and raised life expectancy over time. Now, as the country faces the potentially catastrophic consequences of climate change, the country needs to understand the public health implications of a warming climate.

Progress has been fitful in educating and mobilizing elected officials to address climate-related threats to health and safety. A rising generation, frustrated with the wholly inadequate response, is demanding better. The Juliana 21 are making their case in a campaign they call Our Children's Trust. Their lawsuit aims to compel the federal government to act in their best interest, to secure "the right to a safe climate and healthy atmosphere for all present and future generations."

From our positions as physicians, we believe they have a convincing and compelling case. They were born into this problem; they did not create it. They are uniquely vulnerable: their developing bodies suffer disproportionately from climate change's most serious and deadly harms.

For example, children's lungs are more susceptible to damage from ground-level ozone, caused by pollutants emitted by cars, power plants, refineries and chemical plants, and because they generally spend more time outdoors, their increased exposure can lead to more asthma attacks and emergency room visits.

And childhood development is crucial for subsequent physical and mental health, so the harm they suffer today will leave lifelong wounds, both physical and emotional. Examples include lasting cognitive impairments from malnutrition (studies suggest climate change will cause declines in the production and nutritional values of some crops) the negative consequences of lost school days (from storms, wildfires and worsening heat waves) and the persistence of severe childhood anxiety and PTSD symptoms in the wake of superstorms and severe floods.

Their case has the support of educators and businesses as well as dozens of public health experts, who, together with institutions like the American Academy of Pediatrics and the American Heart Association, recently submitted a powerful amicus brief on their behalf.

It asserts that our nation's youth were "born into a world made hazardous to their health and well-being by greenhouse gas emitted by human activities." It draws our attention to the "broad scientific consensus" that greenhouse gas emissions are causing major changes to the planet, "manifesting as extreme weather conditions, heat waves, droughts and intense storms." It lends additional gravity to the lawsuit's demand that our government respond rapidly and decisively.

We support their effort as physicians bound to a code of medical ethics. We are friends and professional colleagues

continued on next page

Climate Change Lawsuit

continued from page 21

who served two very different presidential administrations. But our views on this issue transcend political affiliation.

We believe this case should go to trial, and not just because these young citizens have a right to be heard. The trial itself, by increasing public awareness, could bring the nation one step closer to consensus on measures like expanded mass transit, incentives to encourage walking and biking and subsidies for cleaner, safer, energy-efficient homes and buildings.

The physician-historian Robert Jay Lifton has suggested the hopeful possibility of a "climate swerve," a major societal change that will lead to rapid, substantive action to address the threat to the climate. He argues that such change requires "an overall theme" that "could rally people of highly divergent political and intellectual backgrounds." The Juliana plaintiffs may have provided us with that theme: our children's trust.

Richard Carmona was surgeon general from 2002 to 2006 under President George W. Bush. David Satcher held that post from 1998 to 2002 under Presidents Bill Clinton and Bush.

What is the biggest fish in the ocean?

The biggest fish in the ocean is the *Rhincodon typus* or whale shark.

Despite their tremendous size and intimidating appearance, whale sharks are commonly docile and approachable. Please keep your distance, giving them the respect and space they deserve.

Whale sharks can grow to 12.2 meters and weigh as much as 40 tons by some estimates! The largest reported whale shark was 20 meters, but it is uncommon to see them longer than 12 meters. They have broad, flat heads with short snouts and their backs have an interesting white, yellow, and grey checkerboard pattern. It is unknown how long whale sharks can live, however, scientists believe they can live approximately 60-100 years.

Whale sharks are found in all tropical and warm-temperate seas around the world, preferring water temperatures of 20-25°C.

Whale sharks eat mostly small organisms like plankton, schooling fish, and squid, which they strain from the water as they swim with their meter-long mouths and specialized teeth.

Source: NOAA National Ocean Service

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NOAA Photo Libraries

Did you know most of NOAA's photos and slides are in the public domain?

NOAA asks only that credit be given to NOAA and the photographer and his/her affiliated organization. More than 80,000 images — housed in the NOAA Photo Library and on Flickr — reflect the expansive reach of NOAA programs and address topics from global climate change to geophysics. They also show NOAA staff at work worldwide, on ships or aircraft. In addition, there are links to the NOAA Sanctuaries and their photo galleries. Access these libraries at (http://bit.ly/2TyNMCt)

2019 Marine Art Contest Winners

As is our policy, we do not list last names for elementary and middle school students.

SCIENTIFIC ILLUSTRATION (all grades)

1 Jessica Dai, gr. 8, Diamond MS, Lexington. *Red-Gilled Nudibranch*

2 Angela Zhang, gr. 10, Lexington HS. *Diatoms*

3 Elizabeth, gr. 8, Covenant Christian Acad., W. Peabody. *Copepods*

4 Amanda Xu, gr. 9, Art Corner Studio, Ann Arbor, MI. *Naked Sea Butterflies*

5 Eloise Mills, gr. 10, Falmouth HS. *Least Tern*

6 Ethan Clifford, gr. 10, Bourne HS. *Atlantic Octopus*

7 Crystal, gr. 8, McCall MS, Winchester. *Sea Gooseberries*

8 Caroline, gr. 7, McCall MS, Winchester. *Great Auk*

9 Kelly Dou, gr. 5, Pike School, Andover. *Black Sea Bass*

10 Courtney Frangioso, gr. 11, Falmouth HS. *Butterfish*

10 Sophia, gr. 6, Jonas Clarke MS, Lexington. *Tubularia Hydroids*

10 Joya, gr. 5, Hillside ES, Needham. *Bluefin Tuna*

10 Angie, gr. 6, Diamond MS, Lexington. *Naked Sea Butterflies*

Honorable Mention

Leo, gr. 5, Hedge ES, Plymouth. *Sea Butterfly*

Kai Chen, gr. 9, Bourne HS. *Red-Gilled Nudibranch*

Sofia Cilfone, gr. 11, Falmouth HS. *Cunner*

Kate Cunning, gr. 10, Cohasset HS. *Bluefish*

Morgan Goodwin, gr. 11, Bourne HS. *Arctic Tern*

Andrea, gr. 5, Merriam Sch./Shi Lin Art Studio, Acton. *Sea Butterfly*

Olivia Guo, gr. 9, Art Corner Studio, Ann Aarbor, MI. *Sea Gooseberries*

Avery Hathaway, gr. 10, Bourne HS. *American Lobster*

Justin L, gr. 6, Concord MS/Shi Lin Art Studio, Acton. *Blue Shark*

Abby Moloney, gr. 11, Falmouth HS. *Bluefin Tuna*

Shu-tong Murray, gr. 11, Falmouth HS. *Northern Basket Star*

Sebastian, gr. 5, Eddy Elem. School, Brewster. *Chalice Sponge*

Isabel, gr. 7, Art Corner Studio, Ann Arbor, MI. *Surf Scoter*

Emelia, gr. 5, Eddy ES. *Scarlet Psolus & Leafy Paddle Worm*

Calista Shank, gr. 11, Falmouth HS. *Chalice Sponge*

Xihong, gr. 8, Shi Lin Art Studio, Acton. *Naked Sea Butterflies*

Neena Xiang, gr. 10, Attic Art Studio, Shrewsbury. *Plankton*

Elita, gr. 6, Art Corner Studio, Ann Arbor, MI. Sabine's Gull

Erik Zou, gr. 12, Roxbury Latin School, Boston. *Atlantic Cod*

COMPUTER GRAPHICS (all grades)

1 Sabrina Stone, gr. 10, Old Colony Reg. Voc. Tech. HS. *Octopus*

2 Trinity Fournier, gr. 9, Old Colony Reg. Voc. Tech. HS. *Food Chain*

3 Christian Hudanich, gr. 10, Norwell HS. *Goosefish*

4 Carrie Wang, gr. 10, Boston.Latin School. *Lion's Mane Jelly*

5 Sophia Shin, gr. 7, William Diamond MS, Lexington. *Moon Snail*

6 Dawson Franco, gr. 10, Old Colony Reg. Voc. Tech. HS. *Dolphin*

7 Rylie England, gr. 9, Old Colony Reg. Voc. Tech. HS. *Naked Sea Butterfly*

8 Aiden Ryan, gr. 10, Old Colony Reg. Voc. Tech. HS. *Crab & other life*

9 Isabella MacWilliams, gr. 9. Pembroke HS. *Basking Shark*

10 Isabel Browne, gr. 11, Cohasset Middle High School. *Atlantic Octopus*

Honorable Mention

Emma, gr. 2, South Elem School, Plymouth. *Seals*

Zoey, gr. 2, Federal Furnace ES, Plymouth. *Lobster/Turtle/Octopus*

Kalebr, gr. 2, Federal Furnace ES. *Shark/Butterfish/Sea Star*

Ella, gr. 2, Federal Furnace ES, Plymouth. *Shark/Sea Star*

Bridget Farias, gr. 10, Old Colony RVT HS. *Moon Jellies*

Leila, gr. 2, Federal Furnace ES. *Dovekie/Dolphin/Worm*

Emma Jones, gr. 9, Old Colony RVT HS. *Pipefish*

Benjamin King, gr. 9, Old Colony RVT HS. *Black Scoter*

Troy Medeires, gr. 9, Old Colony RVT HS. *White Shark*

Samantha Shay, gr. 2, Federal Furnace ES. *Brittle Star/Turtle/Seal*

Allison Umbrianna, gr. 10, Old Colony RVT HS. *Harp Seals*

Chloe Weber, gr. 9, Old Colony RVT HS. *Daisy Brittle Star*

HIGH SCHOOL (grades 9-12)

1 Jayana McGuire, gr. 12, Bourne, HS. Green Sea Turtle & Moon Jelly

2 Haley Johnson, gr. 12, King Philip Reg. HS, Wrentham. *Thick-Billed Murres*

3 Elizabeth Jo, gr. 10, The Bromfield School, Harvard. *Loggerhead Turtles*

4 Helen Tang, gr. 10, Lexington HS. *Least Terns*

5 Abigail Chorches, gr. 11, Falmouth HS. *Octopus*

6 Aayan Patel, gr. 10, Davidson Acad. of NV., Reno. *Kemp's Ridley Turtle & Orca*

7 Eden McKenna, gr. 12, Bourne HS. *Harp Seal*

8 Bridget Berestecky, gr. 9, Bourne HS. *Grubby Sculpin*

9 Miranda Van Mooy, gr. 11, Falmouth HS. *Acadian Hermit Crab*

10 Sophia Hann, gr. 9, Luckie Art Studio, Lexington. *Red Phalaropes*

10 Chiu Tik Nga, gr. 12, Chong Hok Tong Educ. Ctr., Hong Kong. *Two Whales*

10 Chan Pui Yiu, gr. 12, Chong Hok Tong Educ. Ctr., Hong Kong. *Ocean Sunfish*

Honorable Mention

Laura Boutilver, gr. 11, Norfolk County Ag. HS. *Biodiversity in B&W*

Shannon Graves, gr. 12, Falmouth HS. *Northern Gannet*

Madison Halatsis, gr. 10, Norwell HS. *Humpback Whales*

Maya Horta, gr. 12, Bourne HS. *Minke Whale & Great Skuas*

Cheng Oi Lam, gr. 10, School of Creativity, Hong Kong. *Arctic Terns*

Erin Lavin, gr. 12, Falmouth HS. *Pipefish*

Tiffany Lin, gr. 11, Westwood HS. *Thresher Sharks*

Jaden Miranda, gr. 10, Falmouth HS. *Jellyfish*

Yasmin Nyman, gr. 9, Bourne HS. *Lion's Mane Jelly*

Gabriela Polakovic, gr. 9, Falmouth HS. *Green Sea Turtle*

Kestral Powers, gr. 11, Nauset Reg. HS, Eastham. *Green Sea Turtle*

Karolina Simmons, gr. 10, Cohasset HS. *Atlantic Puffin*

Felicity Tu, gr. 10, Westford Acad./Shi Lin Art Studio, Acton. *Leatherback*

Nina Turovskiy, gr. 9, Attic Art School, Shrewsbury. *Orca Hunt*

Kyleigh Waggett, gr. 9, Falmouth HS. *Wolffish*

Rebecca Wilson, gr. 10, Bourne HS. *Northern Gannet*

Jessica Wu, gr. 10, N. Quincy HS. *Biodiversity Illustrated*

Queena Wu, gr. 10, N. Quincy HS. *Whales in our Care*

MIDDLE SCHOOL (grades 5-8)

1 Hantong, gr. 8, Luckie Art Studio, Lexington. *American Lobster*

2 Alicia, gr. 7, Wood Hill MS, Andover. *Atlantic Octopus*

3 Ava., gr. 7, Diamond MS, Lexington. *Sea Raven*

4 Derrek, gr. 7, Li Mao Art Studio, Houston, TX. *Humpbacks*

5 Glen, gr. 5, Fiske ES, Lexington. *Lion's Mane & Moon Jellies*

6 Cindy, gr. 7, Li Mao Art Studio, Houston, TX. *Harp Seals*

7 Jennifer, gr. 8, Charles Brown MS, Newton. *Atlantic Puffins*

8 Candice, gr. 6, Jonas Clarke MS, Lexington. *Least & Common Terns*

9 Maggie, gr. 6, Luckie Art Studio, Lexington. *Jellyfish*

10 Jocelyn, gr. 5, Maria Hastings ES, Lexington. *Little Skate & Sunstar*

10 Aswad, gr. 6, Marshall Simonds MS, Burlington. *White Shark*

10 Angie, gr. 6, Luckie Art Studio, Lexington. *Humpbacks & Diver*

10 Irene, gr. 6, Luckie Art Studio, Lexington. *Orcas*

Honorable Mention

Neal, gr. 8, Marshall Simonds MS, Burlington. *Atlantic Puffiin*

Bohdan, gr. 5, Attic Art Studio, Shrewsbury. *Humpbacks & more*

Abby, gr. 5, Barber MS, Dickinson, TX. *Dolphin*

Michelle, gr. 5, Fiske ES, Lexington. *Atlantic White-Sided Dolphins*

Jennie, gr. 8, Attic Art Studio, Shrewsbury. *Seal & Orca*

An Qi, gr. 8, Li Mao Art Studio, Houston, TX. *Dolphins*

Jacob F, gr. 8, Attic Art Studio, Shrewsbury. *Diverse Marine Life*

Franklin, gr. 8, Charles Brown MS, Newton. *Pipefish*

Jasmine Gu, gr. 5, Harrington ES, Lexington. *Arctic Terns*

Zoe, gr. 7, Wellesley MS. *Dovekies*

Arianna Jiang, gr. 7, West MS, Andover. *Red-Necked Phalaropes*

Yulia, gr. 5, Attic Art Studio, Shrewsbury. *Three Fish Species*

Isabelle, gr. 7, Curtis MS/Shi Lin Art Studio, Acton. *White-Sided Dolphin*

Vivian, gr. 6, John Glenn MS, Bedford. *Loggerhead Sea Turtle*

Cordelia, gr. 8, Shi Lin Art Studio, Acton. *Lion's Mane Jelly*

Lucy, gr. 7, Li Mao Art Studio, Houston, TX. *Humpbacks & Dolphins*

Grace gr. 5, Maria Hastings ES, Lexington. *Shark*

Ayaan, gr. 6, Marshall Simonds MS, Burlington. *Laughing Gull*

Heyi, gr. 5, Leon Sab;atira MS, Pearland, TX. *Herring Gull*

Norah, gr. 5, Eddy ES, Brewster. *Lumpfish*

Edward, gr. 6, Luckie Art Studio, Lexington. *Atlantic Puffins*

Emily, gr. 6, John Glenn MS, Bedford. *Dovekies*

Brenna, gr. 8, Central Tree MS, Rutland. *Razorbill*

Vivian, gr. 7, Belmont. *Roseate Terns*

Alex, gr. 5, Mitchell ES, Needham. *Green Sea Turtle*

Angela, gr. 7, Attic Art Studio, Shrewsbury. *Surface to Seafloor*

ELEMENTARY SCHOOL (grades K-4)

1 Dylan Y, gr. 4, Thoreau School, Concord. *Atlantic Wolffish*

2 Christina, gr. 4, Peter Noyes ES, Sudbury. *Atlantic Puffins*

3 Nancy, gr. 4, Buybank School, Belmont. *Turtle Hatchlings*

4 Chan, gr. K, School of Creativity, Hong Kong. *Long-Tailed Ducks*

5 Grace, gr. 3, Li Mao Art Studio, Houston, TX. *Common Dolphins*

6 Rachel, gr. 4, Alcott ES, Boxford. *Ringed Seal*

7 Cindy, gr. 3, Lt. Job Lane, Bedford. *Arctic Tern*

8 Claire, gr. 3, Lt. Job Lane School, Bedford. *Long-Tailed Ducks*

9 Emma, gr. 4, Douglas ES/Shi Lin Art Studio, Acton. *Gray Seal*

10 Angela, gr. 3, Art Corner Studio, Ann Arbor, MI. *Acadian Hermit Crab*

10 Leah, gr. 4, Burr ES, Newton. *Green Turtle & Jellyfish*

10 Iris, gr. 3, Eliot ES, Needham. *Orca*

Honorable Mention

Luna, gr. 2, Nathan Hale ES, Roxbury. *Sea Butterflies*

Alice, gr. 4, Fiske ES, Lexington. *Harp Seal*

Jayla, gr. 4, Hedge ES, Plymouth. *Zooplankton & Phytoplankton*

Stella, gr. 4, Sparhawk School, Amesbury. *Gray Seal*

Eric H, gr. 2, Blanchard Sch./Shi Lin Art Studio, Acton. *Striped Bass*

Sophia, gr. 4, Maria Hastings ES, Lexington. *Moon Jelly & Comb Jelly*

Zachary, gr. 2, Nathaniel Morton ES, Plymouth. *Anemones*

Edwin, gr. 2, Art Corner Studio, Ann Arbor, MI. *Humpback*

Makayla, gr. 4, Hedge ES, Plymouth. *Zooplankton & Phytoplankton*

Caroline, gr. 3, Nathaniel Morton ES. *Red-Gilled Nudibranch*

Andrea gr. 3, Broadmeadow ES, Needham. *Atlantic Puffins*

Rachel, gr. K, Robinson Sch./Shi Lin Art Studio, Acton. *Common Eider*

Samuel, gr. 3, Crisifulli Sch./Shi Lin Art Studio, Acton. *White Shark*

Ray, gr. K, P. Noyes ES/Shi Lin Art Studio, Acton. *White-Sided Dolphin*

Peter, gr. 4, Ambrose School, Winchester. *Seal*

Lindsey, gr. 4, MCT Sch./Shi Lin Art Studio, Acton. *Red Soft Coral*

Kevin, gr. 1, Art Corner Studio, Ann Arbor, MI. *White Shark*

Bella, gr. 2, Peter Noyes ES/Shi Lin Art Studio, Acton. *Humpback Whale*

Cathryn, gr. 4, Li Mao Art Studio, Houston, TX. *Sea Turtles*

Lanjun, gr. 2, Art Corner Studio, Ann Arbor, MI. *Atlantic Puffin*

Ellliana, gr. 3, Bridge ES, Lexington. *Green Sea Turtle*

Sherry, gr. 4, Abbot Sch./Shi Lin Art Studio, Acton. *Bottlenose Dolphins*

Alicia, gr. 2, Art Corner Studio, Ann Arbor, MI. *Herring Gull*

Andy, gr. 4, Art Corner Studio, Ann Arbor, MI. *Sharks & Prey*

JUDGES' CHOICE AWARDS

exceptional technique or creative interpretation

Marine Mammals: Derrek X, gr. 7, Li Mao Art Studio, Houston, TX. *Humpbacks* – For his attention to detail and artistic composition, focusing on an iconic sanctuary species.

Fishes: Yulia K, gr. 5, Attic Art Studio, Shrewsbury. *Three Fish Species* – For her whimsical interpretation of three unusually shaped and uncommon fishes.

Seabirds: Jennifer L, gr. 8, Charles Brown MS, Newton. *Atlantic Puffins* – For her depiction of a well-loved seabird that flies gracefully underwater.

Sea Turtles: Aayan Patel, gr. 10, Davidson Acad. of NV., Reno. *Kemp's Ridley Turtle & Orca* – For revealing the threat plastic debris becomes in the marine environment.

Invertebrates: Amanda Xu, gr. 9, Art Corner Studio, Ann Arbor, MI. *Naked Sea Butterflies* – For the detailed depiction of this shell-less mollusk in two different states.

Invertebrates/Plankton: Crystal L . gr. 8, McCall MS, Winchester. *Sea Gooseberries* – For her use of fine detail in depicting this small but beautiful species of gelatinous zooplankton