Stony Brook University
School of Marine and Atmospheric Sciences

Stony Brook University, Stony Brook, NY 11794-5000
Tel: 631-632-3187; Fax: 631-632-8820

Annual Report

MOU #AM10560 NYS DEC & SUNY Stony Brook
For the period January 1, 2018 – December 15, 2019

December 15, 2019

The MOU titled, "Development and implementation of an ocean ecosystem monitoring program for New York Bight" between NYS DEC and SUNY Stony Brook School of Marine and Atmospheric Sciences is to develop an interdisciplinary, multi-trophic level-ocean monitoring program in the New York Bight to provide information on the status of New York pelagic resources to managers; and to inform the development of a system of indicators of ecosystem health using existing data and observations collected in the offshore monitoring program to better inform decision making regionally and locally. This report follows the categories of activities found in the scope of work in that MOU.

Contact lead PI, Lesley Thorne (Lesley.Thorne@stonybrook.edu) with questions or comments.

Report Contributors and Project Team: Janet Nye, Associate Professor; Joe Warren, Associate Professor; Charlie Flagg, Research Professor; Alexander Sneddon, Electronics Technician; Jianqiong Zhan, Research Associate; Kurt Heim, Research Associate; Eleanor Heywood, Marine Mammal Technician; Julia Stepanuk, PhD Student; Devan Nichols, Acoustics Technician; Marie Todey, MS Student; Brandyn Lucca, PhD Student; Mark Wiggins, Operational Facilities Manager

We accomplished the following during this annual period:
This report covers the time period of January 1, 2018-December 1, 2019. During that time indicators of ocean health have been accumulated and examined, a glider sampling program has been initiated and five seasonal shipboard monitoring cruises were conducted in July 2018, February 2019, May 2019, July 2019, and October 2019 aboard the R/V Seawolf (Figure 1). The initiation of the offshore monitoring program represents the bulk of work during the time period of this report and will be referred to as "New York Offshore Survey (NYOS)" cruises in objectives 2-5 below.

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Tel: 631-632-3187; Fax: 631-632-8820

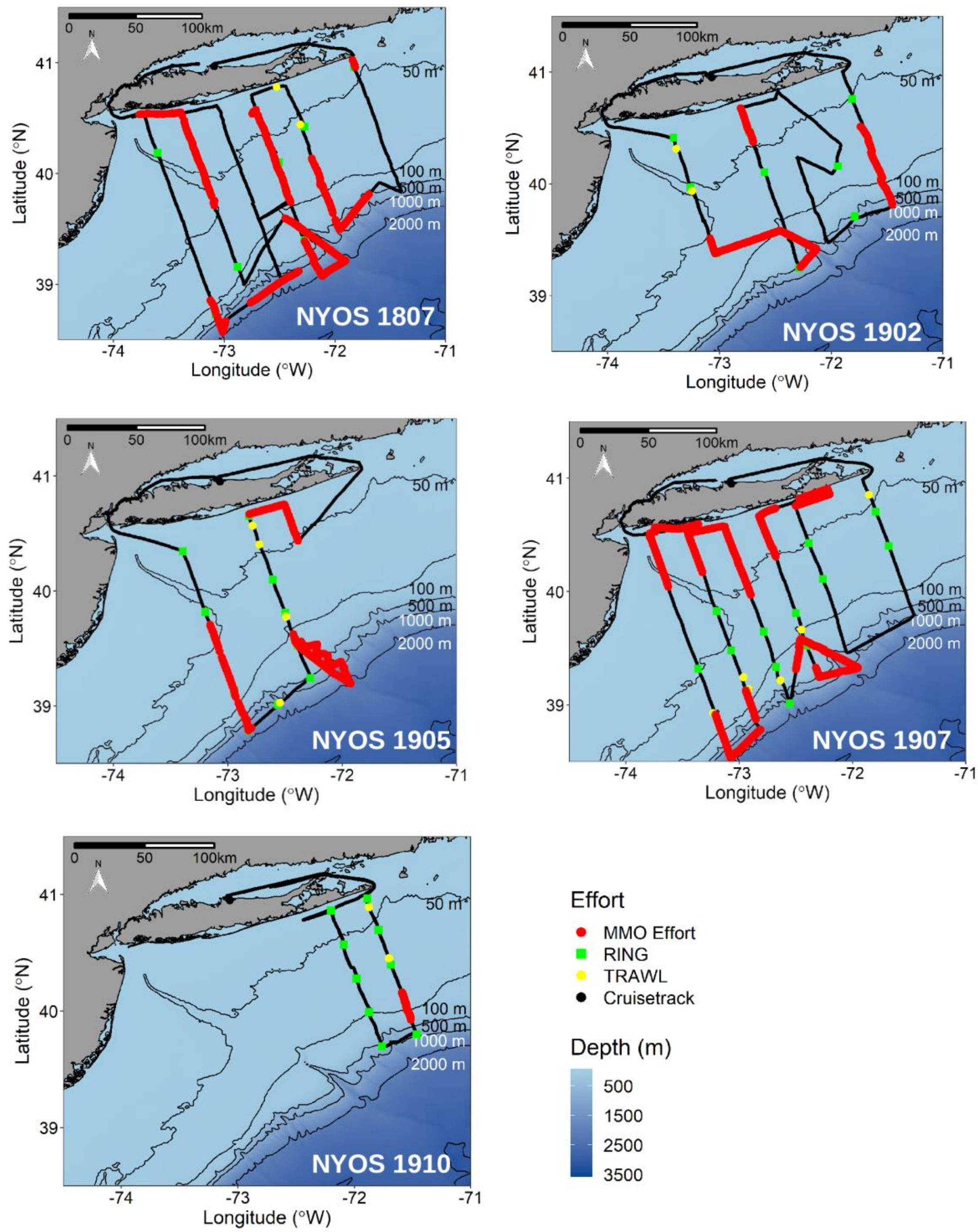

Figure 1. Cruise tracks and locations of various sampling efforts (red: marine mammal observations; green: zooplankton ring net; yellow: fish trawls) for all offshore monitoring cruises that have been completed through October 2019.

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Objective 1: Examination of available data and identifying data gaps

Ecosystem indicators are measurements of key ecosystem components over time that describe the physical, biological, and socioeconomic status of the system. These standardized metrics help scientists and managers to (1) understand natural variability (2) determine what drives this variability (3) quantify human services provided by ecosystems and, importantly, (4) recognize how human activities (i.e., fishing, development, climate change) impact ecosystems. Thus, ecosystem indicators are a fundamental component of Ecosystem Based Management (Link 2010). To better understand, manage, and sustainably use ocean resources in the New York Bight, we reviewed existing datasets that could be used to calculate ecosystem indicators for the NYB. A full report will be provided to NYSDEC in January 2020 summarizing a large number of datasets that are publicly available and appropriate for calculating indicators for the NYB (Table 1). About 200 indicator time series were generated that characterize trends occurring within the NYB study region or in the state of NY. The review also describes additional indicators that could be calculated with existing data (e.g., annual vessel traffic indices, standings of marine mammals, megawatt hours of wind energy produced), and highlights data gaps that are being addressed by the NYOS cruises. After review of the full report, we hope to select the indicators of greatest interest to NYSDEC and stakeholders, and to prioritize the development of additional indicators with further guidance from the NYSDEC.

Table 1. Number of indicators calculated to date during data review and acquisition for Objective 1. Indicators have been calculated for the spatial region of the New York Bight (NYB) or for regions of interest (i.e., New York State, or Long Island).

Category	**Number calculated**	**Example(s)**
Social/Economic	6	Population size (Long Island) Revenue from marine resources (NY)
Commercial	2	Commercial landings (NY) Commercial landings value (NY)
Recreational	11	Striped bass harvest (NY) Total recreational harvest (NY)
Physical environment	36	Marine Heatwaves (NYB) Bottom temperature index (NYB) Hudson River discharge
Lower trophic level	31	Chlorophyll-a concentration (NYB) Total zooplankton biovolume (NYB)
Mid-trophic level (fish)	100	Forage fish abundance index (NYB) Planktivore abundance index (NYB)
Upper trophic level	8	Annual Great Cormorant count (Long Island) Annual Humpback whale strandings (NY)

Two example indicators for consideration are marine heatwave (MHW) statistics and trends in recreational fishing for Striped Bass and Bluefish. Marine heatwaves are prolonged periods where the surface water temperatures are anomalously warm. These are increasing globally (Hobday et al. 2016), but have not been investigated specifically in the NYB. We used surface water temperature

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measurements derived from satellites (Reynolds et al. 2007) and calculated annual MHW statistics for the NYB following methods described in Hobday et al. (2016) and implemented in the R package heatwaveR (Schlegel and Smit 2018). These indicators reveal marked increases in MHWs in the NYB (Figure 2). A second example shows recreational fishing statistics for two popular sportfish in NY, Striped Bass and Bluefish. These estimates are available from the Marine Recreational Information Program (MRIP) led by NOAA. Nearly 2 million Striped Bass were caught and released in 2018 in NY (Figure 3), of which roughly 179,000 were expected to have died after release based on a 9% release mortality (NEFSC 2019). This indicator shows both the impact of human use on fish populations, but also quantifies the importance of living marine resources for recreational purposes and the benefits to residents and visitors to the state of NY.

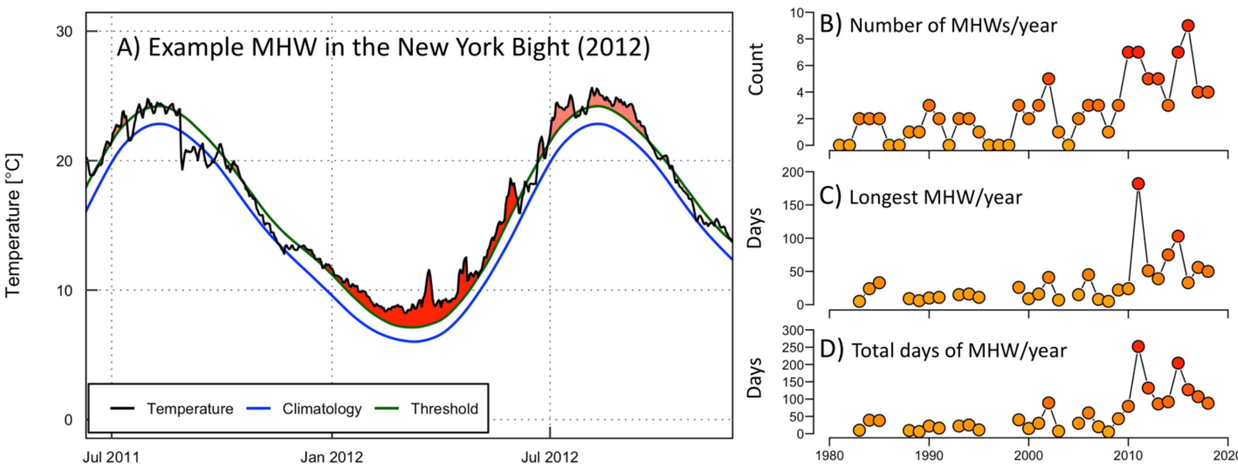

Figure 2. Marine heatwaves (MHWs) in the New York Bight (NYB). Panel A shows how MHWs are identified; the blue line is the 30-year average sea surface temperature, and the green line is the 90th percentile of the 30-year average. When the actual temperature (shown as black line and shaded underneath) exceeds this threshold value for five consecutive days it is considered a MHW event. For example, at the bottom center of the figure one can see the temperature was substantially higher than the 90th percentile for a prolonged period (182 days); this is the longest MHW detected in the NYB with this analysis. Panels B - D show time series (i.e., indicators) which demonstrate MHWs are occurring more frequently in the NYB (B), individual MHW events are getting longer (C), and the annual total of MHW days per year is increasing (D). These trends have important implications for marine organisms.

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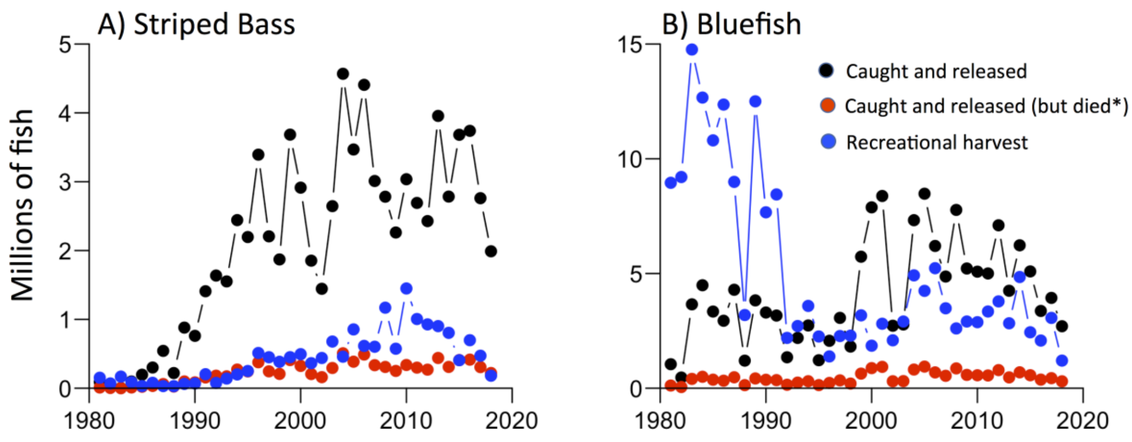

Figure 3. Recreational fishing statistics for New York state for Striped Bass (A) and Bluefish (B) from the Marine Recreational Information Program (MRIP). The lines show recreational catch and release (C&R, black), expected C&R mortality based on a 9% rate used by the NEFSC (red), and recreational harvest (blue). These numbers quantify the impact of recreational fishing on these fish populations, but also the value and benefit of recreational fishing to residents and visitors to the state of NY. Similar indicators can be calculated for other fish species of interest in NY.

Objective 2: Monitor the physical environment including temperature, salinity, fluorescence, and carbonate chemistry

2.1 Shipboard measurements of physical water properties

The physio-chemical environment was assessed on five seasonal cruises where the sampling design employs seven transects that extend from the nearshore to just off the continental shelf. By sampling the water column for physio-chemical properties along each transect we identified and will continue to monitor different water masses that are important habitat for fishes and other marine organisms. In general, the seasonal cycle in physical properties is as described previously, but in just two years of monitoring we see significant interannual variability as indicated by the salinity and temperature. This is best illustrated by a comparison of the cross-sections of the temperature and salinity in July 2018 and July 2019. The location of the thermocline (warm colors) and the coldest near-bottom water (purple) were similar in the New York Bight during the summers of July 2018 and 2019. Stronger stratification occurred in July 2019 as indicated by the larger temperature differences between the upper and lower layer and the bigger salinity difference between the inshore upper layer and offshore lower layer. The "freshest" water (purple and blue colors in lower panel) are found at the surface close to the coast and has its origins in runoff from land. In July of 2019, the Shelf Break Front as defined by the 34 PSU isohaline (yellow colors in Figure 4, lower panel) and warm slope water (red colors indicating higher salinity in Figure 4, lower panel) is located closer to shore and seems to constrain the Mid-Atlantic Cold Pool (purple in Figure 4, upper panel), which does not extend as far offshore in 2019. This means that much less cold-water habitat was available to benthic organisms in the summer of 2019 and that waters offshore were about 5-10°C warmer in the summer of 2019 as compared to the

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summer of 2018. Recent work suggests that a fundamental change in ocean dynamics occurred after 2000 where now a greater number of warm core rings that have spun off from the Gulf Stream influence the Northeast Shelf (Gangopadhyay et al. 2019). These warm core rings influence shelf water temperatures and may contribute to the more frequent marine heat waves in the New York Bight and Northeast US that have been observed (Gawarkiewicz et al. 2019). We are using the data collected on our seasonal cruises to understand the physical dynamics as well as to quantify the location and spatial extent of the Mid-Atlantic Cold Pool as well as the location of the Shelf Break Front.

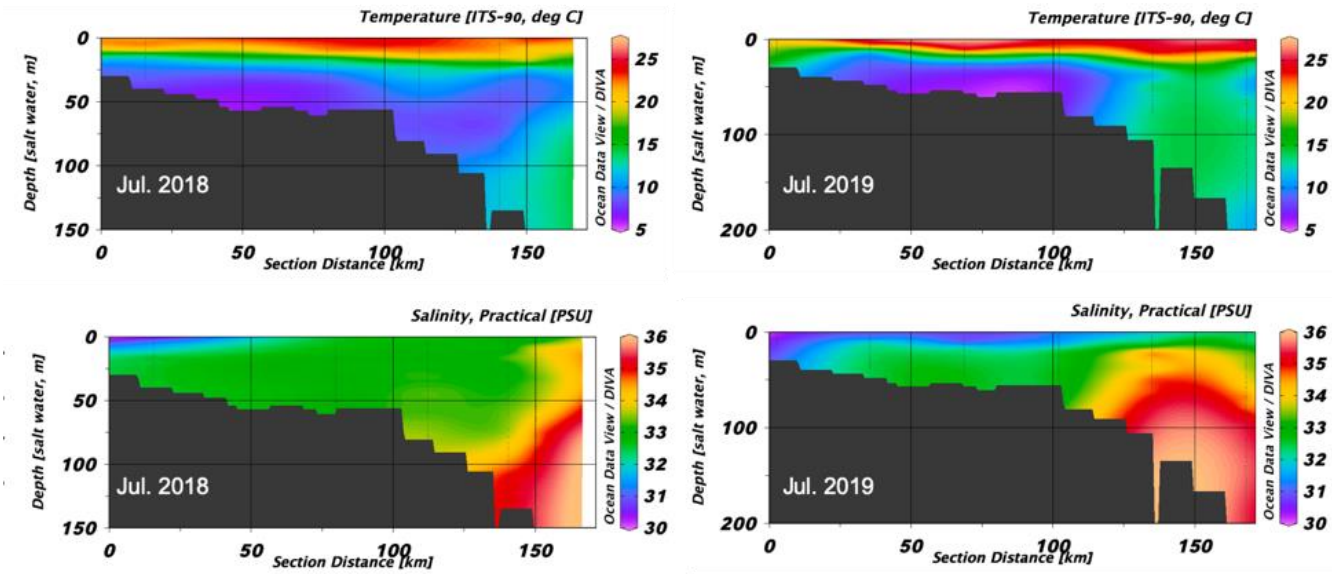

Figure 4. Temperature and salinity across the New York Bight in July 2018 (the left panel) and July 2019 (the right panel). The upper panel shows the temperature with red indicating warm water and the purple areas representing the coldest water of the Mid-Atlantic Cold Pool near the bottom. The Mid-Atlantic Cold Pool is the cold water that gets trapped by thermal and can be defined as any water inside the 10 ° Celsius isotherm over the shelf. The lower panel shows the salinity, red indicating salty slope water heavily influenced by the Gulf Stream. In July of 2019, the Shelf Break Front as defined by the 34 PSU isohaline (yellow) is located further onshore and the Mid-Atlantic Cold Pool (purple) does not extend as far offshore.

2.2 Carbonate Chemistry

In addition to hydrographic physical measurements, the spatial and temporal distribution of ocean surface CO_2 fugacity (fCO_2, µatm) and pH were determined using a General Oceanic pCO_2 measuring system and a Sunburst pH sensor. Water samples and pH were also taken at depth during CTD casts along the cruise track shown in Figure 1. Surface fCO_2, the effective partial pressure of CO2 after considering temperature and other factors, clearly shows seasonal variability in the region with higher values during summer and lower values during winter (Figure 5). In the summer, there is a general decrease in fCO_2 from inshore stations associated with terrestrial inputs to offshore water that are influenced by the Gulf Stream. In winter fCO_2 was higher close to shore and increased in offshore waters in the winter. The hydrography and circulation of the region can be conveniently divided into

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three distinct regimes – the River Plume (fresh and warm water), the Cold Pool (cold water) and the slope water (warm saline water), all of which have different factors affecting carbonate chemistry that are reflected in the spatial patterns with season. These regions are particularly obvious in Figure 5 (left panel) with dark purple areas showing regions influenced by freshwater input and light colors offshore representing the influence of warmer saltier water.

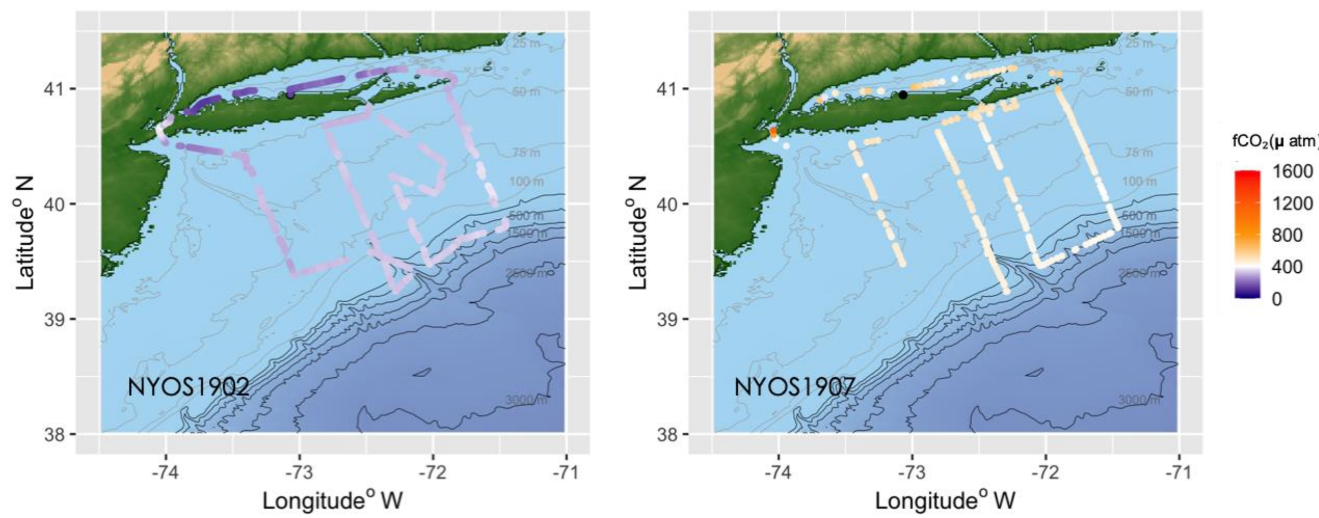

Figure 5. Ocean Surface CO_2 fugacity fCO_2 (µatm) status in 2018-2019. Note the region has lower values during winter (NYOS1902) and higher values during summer (NYOS1907).

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The pH values in surface waters in the NY Bight are currently relatively high (Figure 6a). However, pH is much lower in waters at depth (Figure 6b). In particular, the Cold Pool has some of the lowest pH values in the region (red areas in Figure 6c) in part because cold water absorbs more CO_2 from the atmosphere in the winter and then trapped near the bottom as the Cold Pool is formed during stratification. Analysis of water samples collected during CTD casts will allow us to quantify the saturation state of these waters and only then can we determine whether these waters might impair growth and survivorship of fish and shellfish.

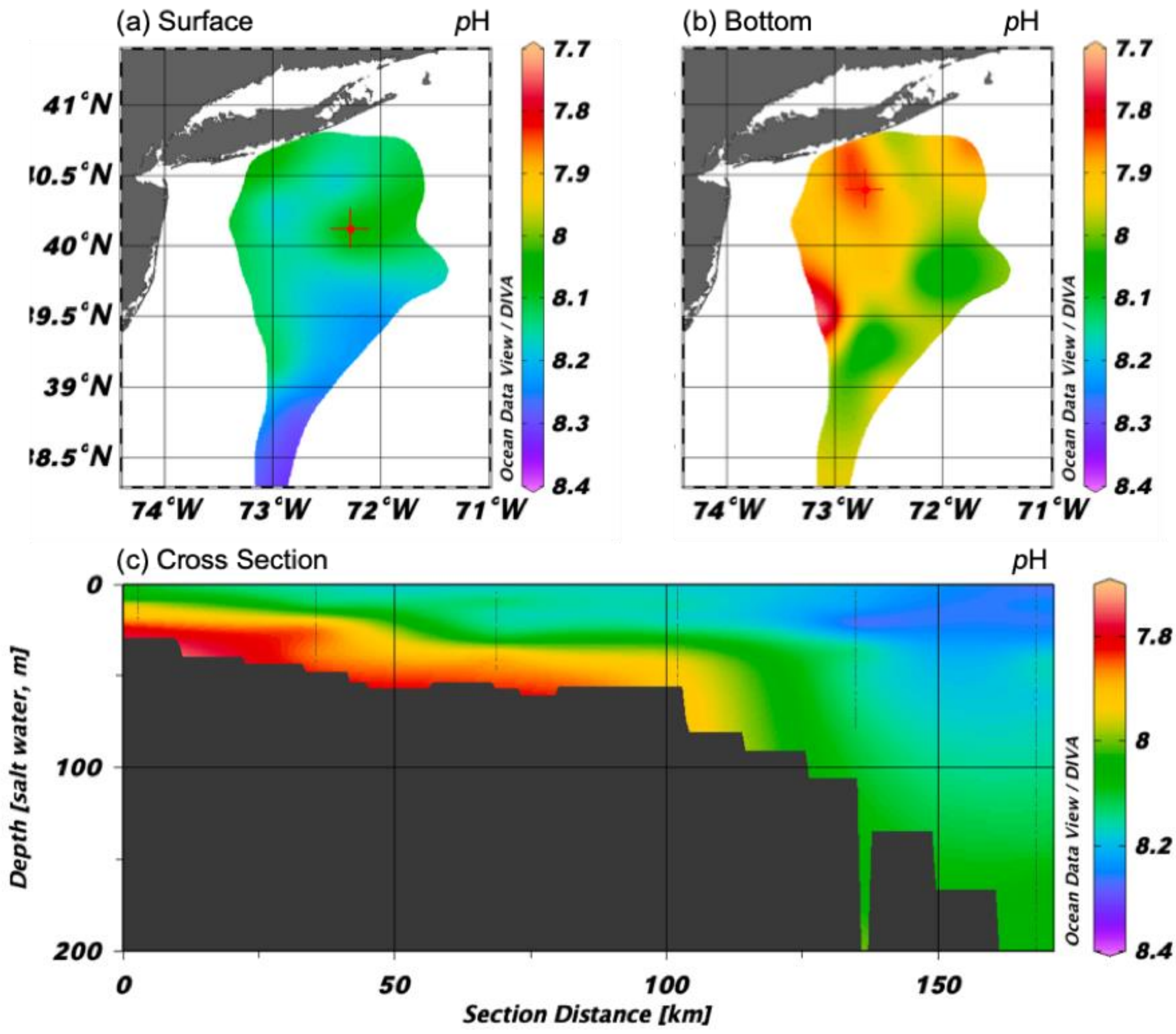

Figure 6. Surface waters (a) are typically well above pH of 8, but pH is much lower at depth (b,c). The low pH (red) in bottom waters of the NYB in the summer (July 2019) are potentially stressful conditions for fish and shellfish and are collocated with the NYB Cold Pool, an important habitat feature for shellfish and other marine organisms.

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2.3 Glider Operations

The Slocum G3 ocean glider from Webb Research arrived in late 2018. The Slocum G3 glider (Figure 7) is 190 cm long, 20 cm in diameter and weighs 61.5 kg in air (75" long, 8" dia and 136 lb). The SoMAS glider, SBU01, is equipped with a SeaBird pumped CTD for temperature, salinity and pressure, a Wet Labs FLBBCD fluorometer for chlorophyll, CDOM and backscatter, and an Anderraa Optode for dissolved oxygen. In addition, the glider is equipped with short-wave and satellite radios, a GPS receiver and an ARGOS transmitter. The weight of the glider and its fore-aft distribution is carefully adjusted to within a gram or two so that the glider is neutrally buoyant in the near surface waters where it is to be deployed. The glider then operates in a series of dives and climbs (yo's) coming to the surface at ~3 hour intervals to establish two-way satellite communication to shore to transfer data and receive new mission commands as needed.

Figure 7. The SoMAS Slocum G3 ocean glider being lowered into the ballasting tank.

Early trial deployments in local waters occurred in March, April and May with the first real deployment that sent the glider across the shelf starting on July 16th. This first deployment lasted 27 days covering some 470 km and characterized summer conditions in the New York Bight (Figure 8a). Recovery of the glider off Sandy Hook was accomplished in collaboration with the group at Rutgers who were recovering one of their own gliders. The second deployment, covering fall conditions, started on October 14th, lasted 32 days and covered some 670 km (Figure 8b). Recovery again was off Sandy Hook using the Rutgers vessel. All deployments have and will start offshore of Shinnecock Inlet using one of the SoMAS Southampton boats and end along the New Jersey coast, generally off Sandy Hook.

The summer and fall glider cruises covered nominally the same area of the New York Bight although the summer cruise was limited to the inner two thirds of the shelf because we were using battery power too quickly. Nevertheless, the cruises showed the essential features of the summer and fall conditions.

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The main feature of the summer hydrography of the New York Bight is the Mid-Atlantic Cold Pool, a feature in which cold winter water with relatively high nutrient levels is overlain by the summer pycnocline. During the summer a 10-20m thick warm surface layer had temperatures that ranged up to ~26^{o}C while minimum bottom temperatures, characteristic of the Cold Pool, were in the 6-8^{o}C range (blue in Figure 9a). The Cold Pool extends from nearshore, although exactly where that boundary is located is highly variable, to the edge of the shelf and out over the shelfbreak front.

a) SBU01 Summer cruise track,
July 16 – August 12, 2019

b) SBU01 Fall cruise track,
October 14-November 15, 2019

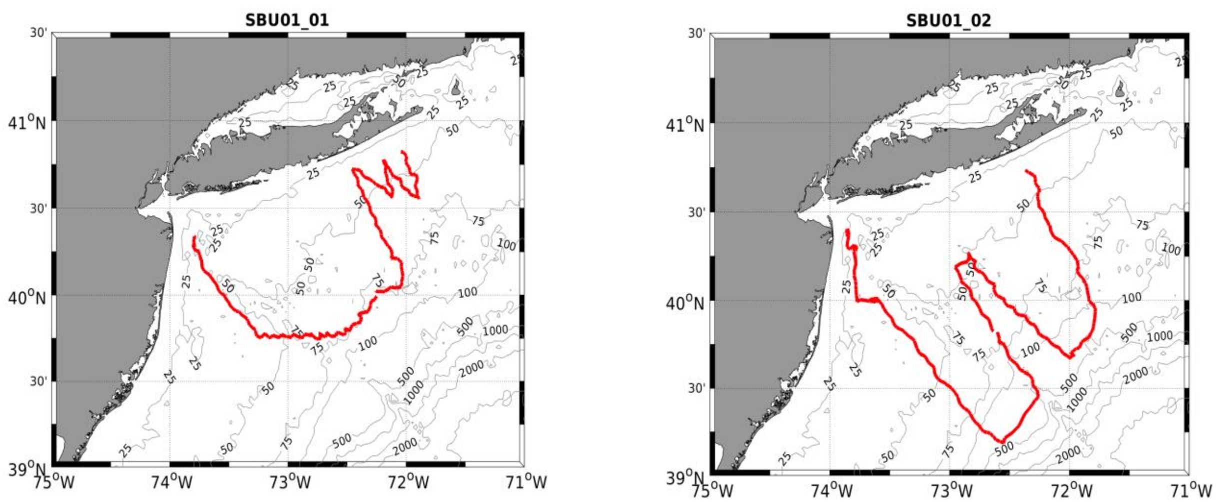

Figure 8. Glider cruise tracks for the first (left) and second (right) deployments. Good coverage of both the inshore/offshore regions and east-to-west areas were obtained with both deployments.

The fall is the time of transition from the highly stratified conditions of the summer to vertically uniform winter conditions as fall cooling and strong storms erode the stratification and lead to the seasonal end to the Cold Pool. The fall transition, however, is an episodic process. The water column does not mix gradually, but rather storm events mix the water column rather abruptly. The result of this mixing shows up in the glider data where the strong vertical gradient in temperature is absent (Figure 9b). A few significant nor'easters prior to the launch of the glider in October started the erosion of the temperature stratification. Another storm occurred as the glider reached the edge of the shelf and then headed back north. You can see the impact of the earlier and later storms in the temperature section where there were still some warm waters left during the first cross-shelf leg, October 15-20, which had completely disappeared as the glider re-crossed the shelf, October 26-31. That over-turning and mixing produced temperatures on the shelf that were nearly the vertical mean of the late summer temperatures, with little evidence of significant heat loss. The very warm water encountered at the edge of the shelf seen in the two offshore portions of the cruise show the impact of the warmer and more saline waters of the slope sea on the shelf-slope front.

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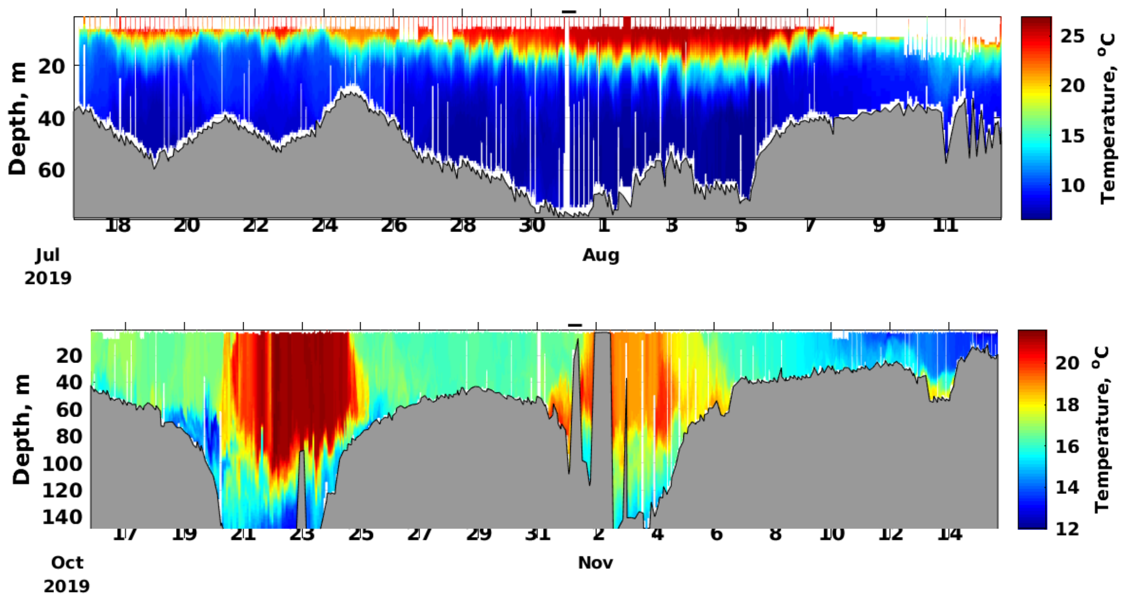

Figure 9. Vertical along-track temperature sections from the summer, top, and fall, bottom, glider, deployments. Note the vertical fluctuations in the summer thermocline. These are the result of semi-diurnal internal tides generated over the slope that propagate shoreward across the shelf.

Figure 10 shows one of the aspects that unites the physical features with the biology of the New York Bight. In the upper panel is the vertical distribution of the chlorophyll along the track while the lower panel shows the center of the pycnocline indicated by the Brunt-Vaisala frequency profiles, which shows the intensity of the vertical stratification (Figure 10). The location of the phytoplankton as evidenced by the chlorophyll (Figure 10, top) and dissolved oxygen (not shown) distributions between 2- and 40 m, well below the bottom of the warm surface layer. The phytoplankton need the light from above and some level of stratification to flourish but they also need a supply of nutrients which, in the case of the summer conditions, comes from the remnant winter waters in the Cold Pool. The net result is that the phytoplankton, as well as the various levels of the food chain that depend upon primary production, occur near the middle of the water column.

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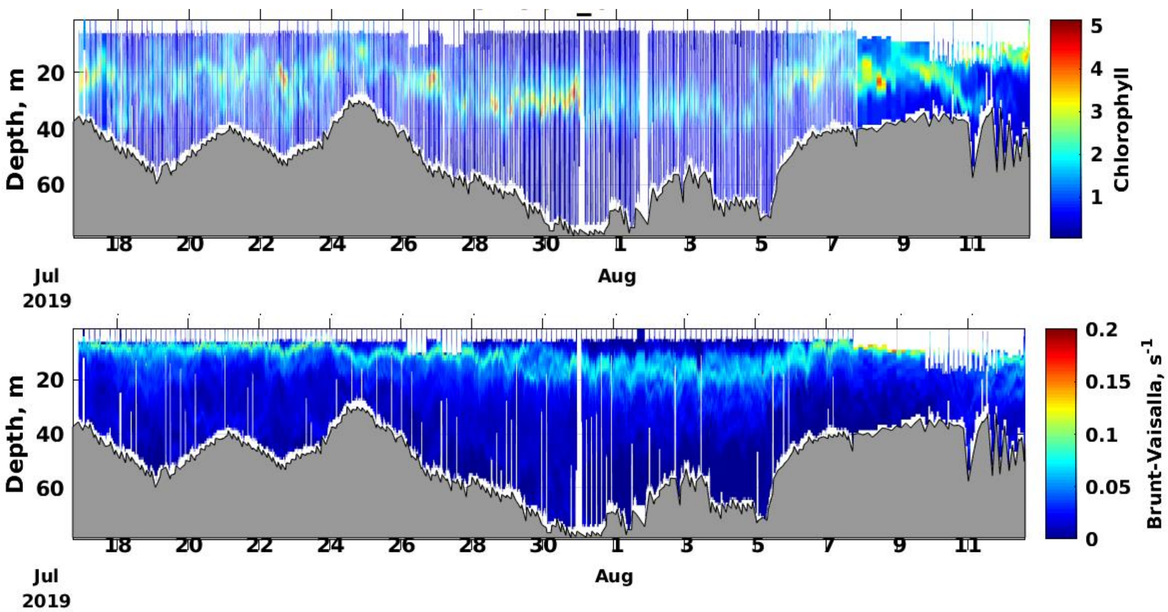

Figure 10, Summer distributions of chlorophyll, ug/l, top, and Brunt-Vaisala frequency, bottom, for the summer deployment.

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Objective 3: Characterize lower trophic level productivity

Zooplankton ring net tows occurred at roughly a dozen hydrographic stations during each research cruise. Net tow stations are selected to provide broad spatial coverage (east to west as well as inshore to offshore) and are mostly at dusk or night to minimize biases due to zooplankton vertical migration. The net (60 cm diameter, net mesh 333 μm) is hauled vertically from a depth of 25 m to the surface. The biovolume of the catch is measured, then each sample is preserved in jars fixed with 10% formalin, 90% seawater.

Samples are taken back to the lab where a subsample of organisms are identified (to species level when possible), enumerated, and photographed (Figure 11). The lengths of a subset of the most common organisms are also recorded. These data are then used to produce estimates of the numerical abundance (# of animals / m^3) at each sampling station (Figure 12). Sample analysis has been completed for the 2018-07 (10 stations), 2019-02 (9 stations), and 2019-05 (10 stations) cruises. The analysis of the two most recent cruises, 2019-07 (12 stations) and 2019-10 (12 stations), are in progress. For the cruises analyzed so far, the most abundant organisms caught are copepods, amphipods, chaetognaths, and cladocerans. Other organisms found frequently include gelatinous zooplankton (ctenophores, siphonophores, medusa), pteropods, decapod larvae, and larval fish.

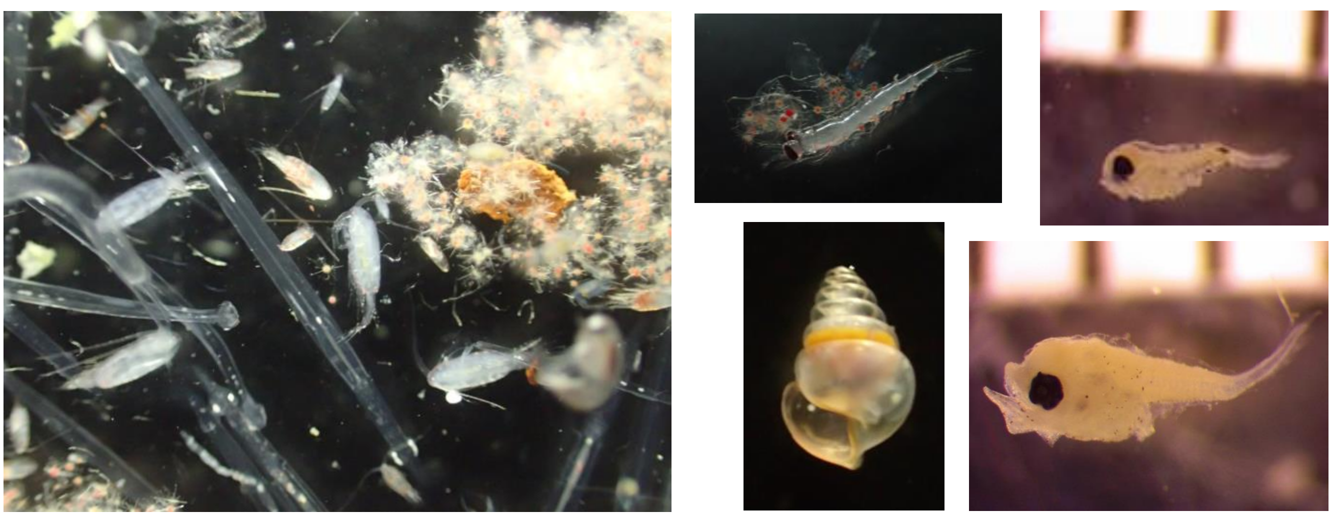

Figure 11. A variety of organisms are caught in the net including: copepods and chaetognaths (left), decapods (upper middle), pteropods (lower middle), and larval fish (*Phycidae sp.* (hake), upper right; *Mugilidae sp.* (mullet), lower right).

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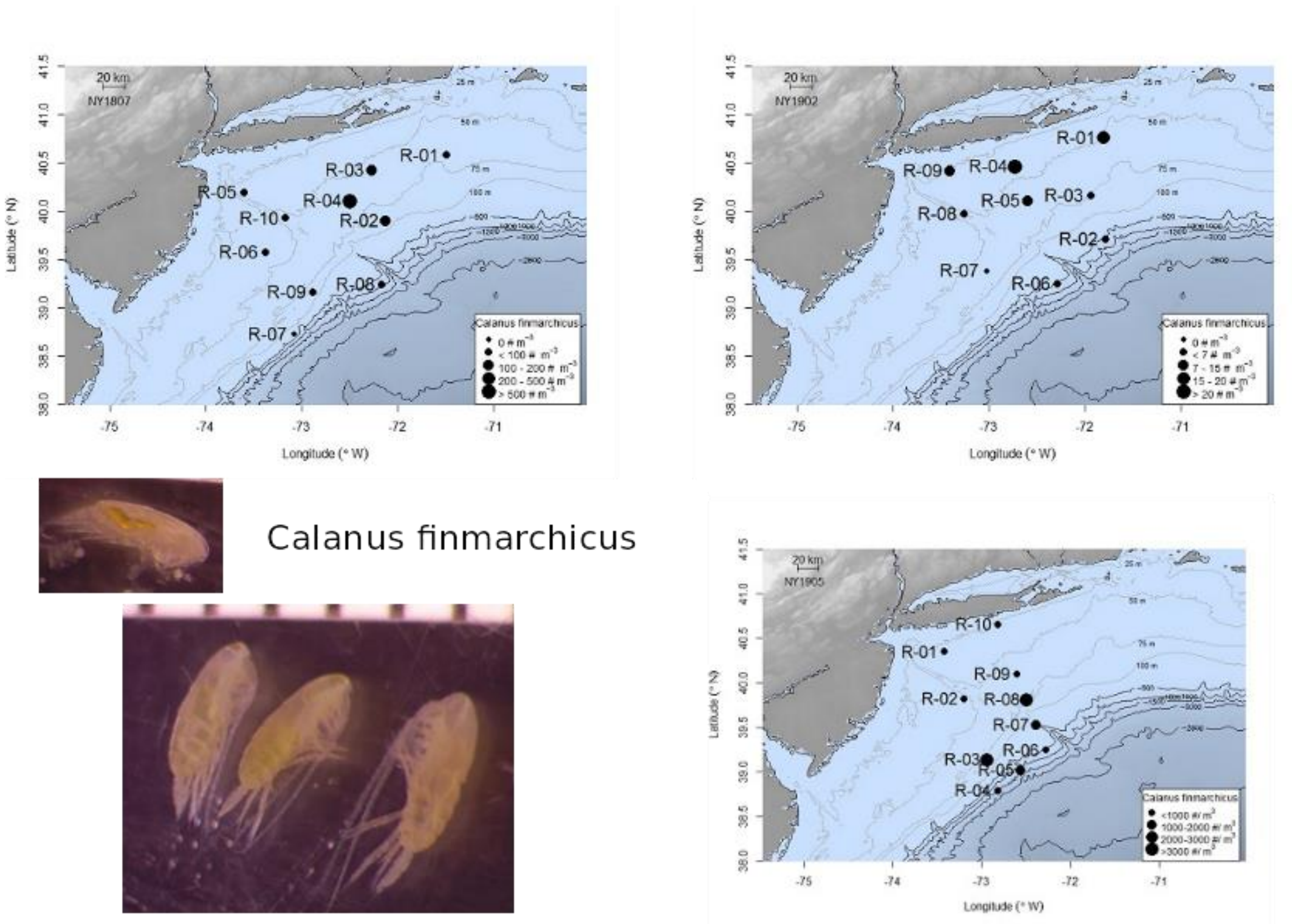

Figure 12. The first three cruises (July 2018, upper left; February 2019, upper right; May 2019, lower right) captured seasonal variations in the abundance of the copepod, *Calanus finmarchicus*, an important prey item for many fishes that support commercial and recreational fisheries as well as top predators including seabirds and right whales. The highest abundances occurred in late spring (1000s animals / m^3 in 2019-05), decreasing through the summer (100s animals / m^3 in 2018-07), and very few animals present in the winter (10s animals / m^3 in 2019-02).

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<u>Objective 4: Quantify abundance and distribution of pelagic fishes and squid in the New York Bight.</u>

Multiple-frequency (38, 70, 120, and 200 kHz) scientific echosounders are used to record the backscatter from pelagic fish and squid from a few meters below the surface to the seafloor continuously during each survey (Figure 13). Acoustic surveys are widely used throughout the world to assess fish stocks and in conjunction with net trawl ground-truthing this method can provide quantitative measures of pelagic fish and squid abundance and distribution. Acoustic backscatter measurements are processed to remove noise and scattering from non-biological sources (mostly bubbles near the surface produced by wind and waves). The backscatter at each individual frequency is then integrated both horizontally and vertically (Figure 14). Fish that contain swimbladders scatter sound differently than non-swimbladdered fish or crustacean zooplankton. These differences can be exploited by combining information from two or more frequencies to identify and discriminate backscatter caused by swimbladdered fish or other scatterers.

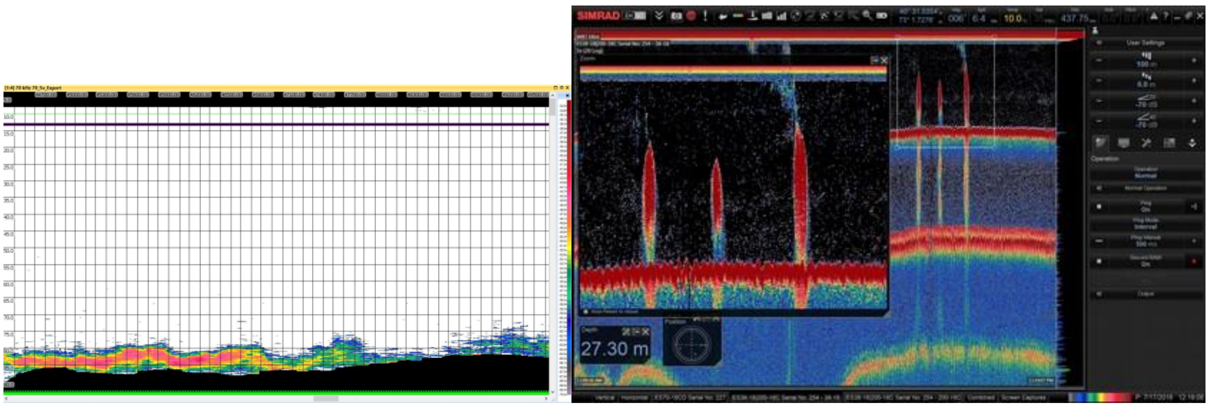

Figure 13. Echograms (vertical axis shows depth, horizontal axis shows distance, color corresponds to how much backscatter occurred) show the distribution of fish and other scatterers in the water column including near-bottom fish layers (70kHz echogram, left) and dense, mid-water fish schools (38kHz echogram, right). These instruments can provide detailed information on the volume and location of schools or scattering layers with high resolution in both the horizontal (meters) and vertical (10s cm) dimensions. The backscatter data can be integrated vertically and horizontally to produce maps showing the spatial distribution of pelagic organisms throughout the study region (Figure 14).

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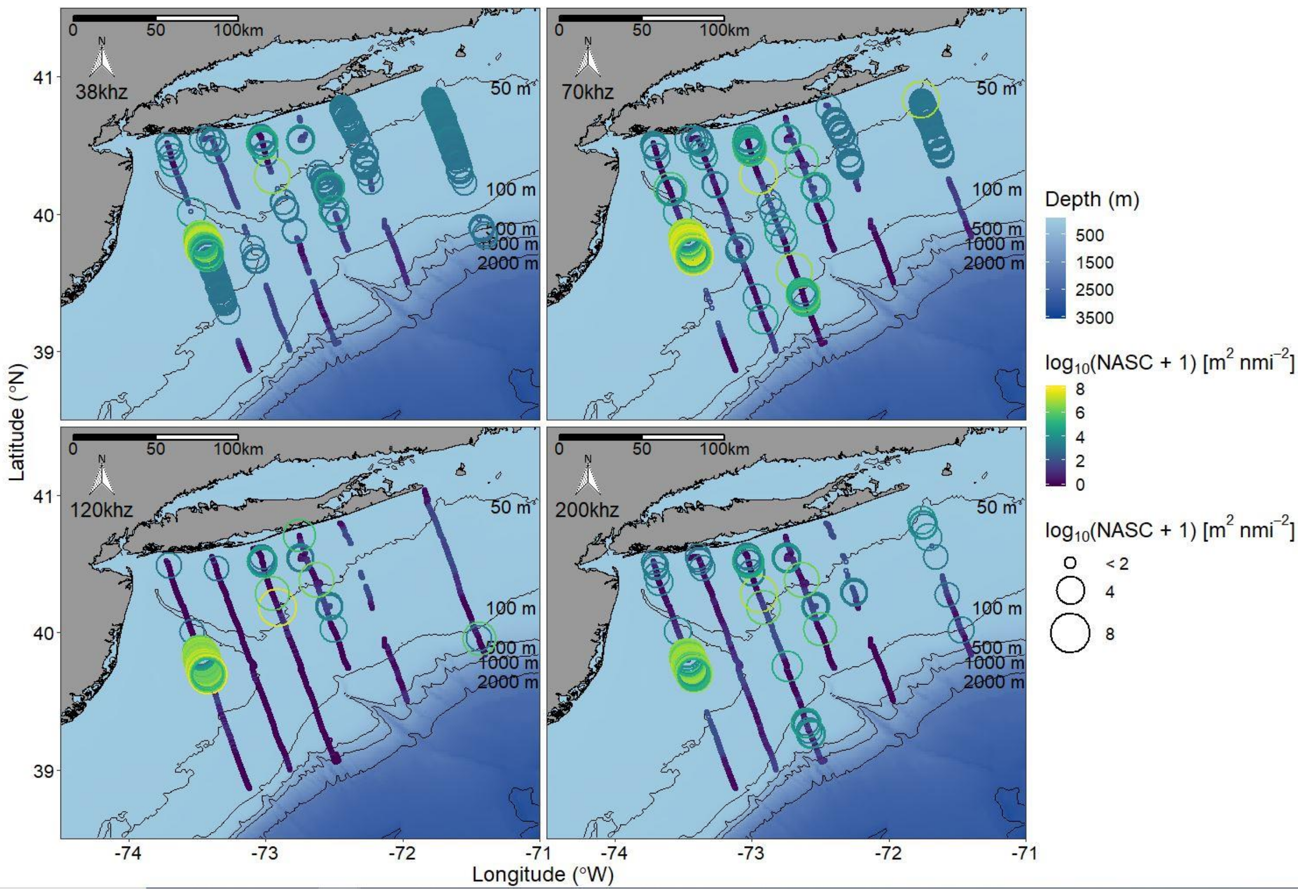

Figure 14. Fishery acoustic surveys produce spatial maps of NASC (Nautical Area Scattering Coefficient). Here each panel represents NASC for a different frequency for the July 2019 survey. The color and size of each circle are scaled to how much backscatter occurred at that location. For many species of interest, NASC (at a specific frequency) will be proportional to animal biomass with lower frequencies (38 and 70 kHz, top panels) measuring scattering from swimbladdered fish and higher frequencies (120 and 200 kHz, bottom panels) measuring scattering from non-swimbladdered fish or zooplankton. These maps can be used to identify areas where large biomasses of pelagic organisms are found or occur regularly which can be useful for marine planning purposes. Preliminary analysis of the acoustic data from the first four surveys show that our surveys can capture and quantify seasonal variations in both pelagic zooplankton and fish abundance.

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It can be challenging to quantify the acoustic scattering contributions from different types of fish, especially when they are co-located so regular fish trawls are conducted during the cruises when aggregations of fish or squid are encountered. These trawl contents can provide physical specimens of fish or squid for other analyses in addition to their use for verifying acoustic measurements (Figure 15).

Figure 15. Trawls collect fish which are measured and weighed onboard the R/V Seawolf with a subset of individuals frozen for later analysis. Commonly caught organisms include: longfin and shortfin squid, Atlantic menhaden, butterfish, silver hake, Atlantic mackerel, black sea bass, and larger zooplankton (salps, jellyfish, ctenophores). Less common organisms that have been caught on more than one cruise include: northern puffer, krill, shrimp, red hake, spotted hake, pearlsides, myctophids, smooth puffers, moon fish, round herring, northern sea robin.

Objective 5: Collect opportunistic sighting and behavioral data of cetaceans in the New York Bight

Marine apex predators are conspicuous, highly mobile animals that integrate resources throughout food webs, and can act as sentinels of ecosystem change (Boersma 2006, Moore 2008, Groskreutz et al., 2019, Hazen et al. 2019). Thus, monitoring apex predators can provide valuable information on the status of marine ecosystems. Together, line transect and photo-ID monitoring efforts will elucidate habitat characteristics for individual species, and will provide important baseline data on the abundance, distribution, species composition and seasonal habitat use of both small and large cetaceans in the NYB against which future change can be compared. Thus, we conducted standardized shipboard line-transect surveys (Buckland et al. 2001) to monitor the abundance and distribution of cetaceans in the NYB during daylight hours on the five NYOS research cruises conducted to date (July 2018, February 2019, May 2019, July 2019, and October 2019). This survey effort has resulted in a total of 115 sightings of 11 confirmed species of cetaceans (Table 2, Figure 16). Photo-identification (photo-ID) surveys of humpback whales, bottlenose dolphins, pilot whales, and beaked whales were conducted whenever close approaches to these species were possible. Photo-ID images are being contributed to the following photo-ID catalogues in order to facilitate matches of individuals between regions and through time: the New York Bight Photo-Identification Catalog (contributors include the Atlantic Marine Conservation Society, the Coastal Research and Education Society of Long Island, Gotham Whale, Inc., the Wildlife Conservation Society and this program) and the Gulf of Maine

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Tel: 631-632-3187; Fax: 631-632-8820

catalog maintained by Allied Whale for humpback whales; the Mid-Atlantic Bottlenose Dolphin Photo-ID Catalogue for bottlenose dolphins, and the Duke University photo-ID catalogs for pilot whales and beaked whales. Images for these species in the NYB will provide much-needed information on the movements and residency of individual animals, and to the stock structure of these species along the eastern seaboard of the US. Line-transect surveys are being conducted concurrent with oceanographic and fisheries acoustics surveys, and ongoing integrative analyses of these interdisciplinary datasets will allow us to better understand drivers of marine mammal abundance and distribution and trophic interactions between mid and upper trophic levels through the course of this monitoring program (Objective 6).

Table 2. Summary of cumulative marine mammal sightings and total number of individuals observed during all NYOS cruises (summer 2018 through fall 2019).

Common Name	Scientific Name	No. sightings	Total no. individuals
Atlantic spotted dolphin	*Stenella frontalis*	1	60
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	1	15
Common bottlenose dolphin	*Tursiops truncatus*	17	162
Cuvier's beaked whale	*Ziphius cavirostris*	2	9
Fin whale	*Balaenoptera physalus*	10	26
Humpback whale	*Megaptera novaeangliae*	7	27
Minke whale	*Balaenoptera acutorostrata*	2	2
Pilot whale spp.	*Globicephala spp.*	3	37
Risso's dolphin	*Grampus griseus*	13	106
Short-beaked common dolphin	*Delphinus delphis*	26	474
Sperm whale	*Physeter macrocephalus*	1	1
Unidentified cetacean	NA	22	25
Unidentified medium delphinid	NA	2	2
Unidentified small delphinid	NA	7	31

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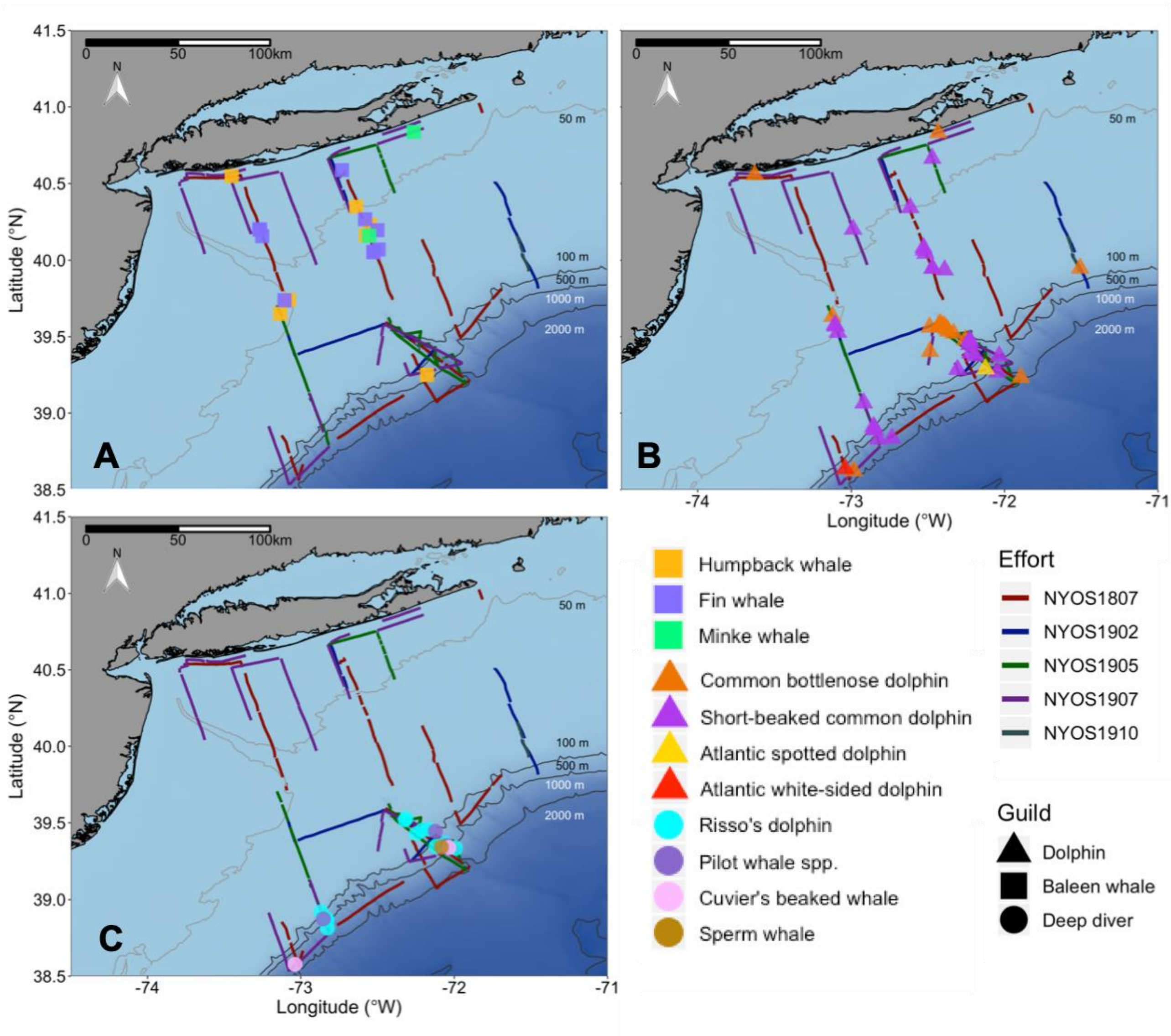

Figure 16. Marine mammal sightings and line transect survey effort in the NYB for (A) large whales, (B) dolphins, and (C) deep diving cetacean species. Colored lines show survey effort for each cruise, while cruise names reflect the year and month of each survey.

In addition to line transect and photo ID surveys, we conducted photogrammetry studies of humpback whales in the NYB using drones or Unmanned Aerial Vehicles (UAVs). The NYB provides important foraging habitat for humpback whales during summer months, when humpback whales build up energy stores to use when fasting during the breeding season (Lockyer, 1987; Vikingsson, 1990; Christiansen et al., 2013, 2016). Sightings of humpback whales are thought to have increased in the NYB in recent years, possibly due to increases in Atlantic menhaden (Brown et al. 2018), and local reports suggest that most humpback whales foraging in the NYB are juveniles. However, adult whales have been observed in offshore waters, and it is unclear whether juveniles are observed more frequently due to

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Tel: 631-632-3187; Fax: 631-632-8820

higher observer effort in inshore regions of the NYB. Further, little is known about foraging behavior and prey availability for humpback whales in the NYB. To address these gaps in knowledge and to provide an indicator of resource availability in the NYB through time, we are quantifying the body size and body condition of humpback whales using UAV measurements (Groskreutz et al. 2019; Figure 17).

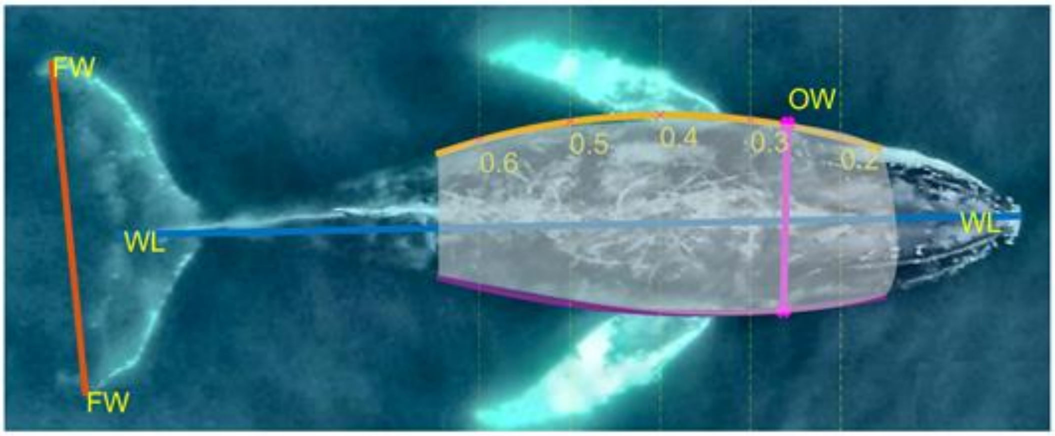

Figure 17. Example of measurements taken from UAV imagery of humpback whales. The shaded region is the area measured for the body condition calculation (called Body Area Index, or BAI), and is bounded by the two parabolas represented by individual orange and purple lines. This region in the mid-section of the body is used to assess body condition because this region shows the greatest variability through time (Vikingsson et al., 1990; Miller et al., 2012; Christiansen et al., 2016; Burnett et al., 2018). BAI is calculated by obtaining the surface area between the 20th and 60th percentile of the two parabolas and normalizing it by the length squared (Burnett et al. 2018). WL is the total length of the individual, FW is the fluke width, and OW is the maximum width of the whale (UAV image: J Stepanuk under NOAA LOC 21889 to L. Thorne)

To quantify humpback whale body condition, we obtained high quality images of individual whales at the surface along with high resolution measurements of altitude using a lightweight LiDAR laser altimeter mounted on the UAV. To date we have measured the length and body condition of 30 individual humpback whales. Photo-ID efforts confirmed that four individuals were measured on multiple occasions and one individual was measured between years, allowing comparisons of body condition through time at an individual level. Analyses of body condition are ongoing, and multiple measures of body condition (Christiansen et al. 2016, Dawson et al.2017, Burnett et al. 2018) are currently being explored to determine the most appropriate metric to detect body condition changes for humpback whales throughout the feeding season in order to develop a baseline for humpback whale body condition in the NYB.

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In addition to BAI analyses, UAV surveys are providing important data to support studies of humpback whale habitat use. Length measurement from UAV imagery have allowed us to distinguish juvenile and adult whales, and preliminary observations suggest that humpback whales occurring inshore are juveniles, while adults are occurring in offshore waters. UAV imagery highlighted the surface foraging behavior of humpback whales in the NYB (Figure 17). There is an ongoing Unusual Mortality Event (UME) for humpback whales on the Atlantic coast in which elevated humpback whale mortalities have been observed, with mortalities observed in NY. The UME is suspected to be due to ship strikes (www.fisheries.noaa.gov). It is possible that the surface feeding behavior observed in the NYB may put humpback whales in this region at particular risk of ship strike, and our ongoing analyses of humpback whale sightings and UAV imagery will allow us to assess whether patterns of habitat use and foraging behavior in humpback whales increase the susceptibility of whales to ship strikes.

Figure 17. Humpback whale feeding on surface aggregations of menhaden in the New York Bight (UAV image: J. Stepanuk under NOAA LOC 21889 to L. Thorne)

Objective 6: Characterize trophic interactions and oceanographic drivers of living marine resources

In Years 1-2, our focus was on collecting data synoptically that can then be used to understand how oceanographic features affect the abundance and distribution of pelagic organisms. The above maps and figures represent the first stages of this analysis. To satisfy Objective 6, we will begin to combine these data to determine to what degree higher trophic level organisms like fishes and whales covary with their prey and the degree to which physical features like the Mid-Atlantic Cold Pool and Shelf Break Front structure the environment to enhance trophic interactions. We have already started to make connections between some of the oceanographic features and its influence on lower trophic level organisms (Figure 10), but other figures suggest strong associations of pelagic organisms in the Hudson River plume, perhaps near the onshore edge of the Cold Pool (Figures 4,14). Additionally, preliminary analysis of the acoustic backscatter data discriminating between zooplankton (primary consumers) and fish (secondary consumers), shows that the acoustically-measured biomass of these two groups are distributed differently across the study region (Figure 19). Fine scale physical data combined with acoustics data, trawls and marine mammal sightings will allow us to develop predictive habitat models that could ultimately be used to project the effects of climate change in the New York Bight. In addition to BAI UAV research discussed in Objective 5, UAV studies will be investigating fine-scale interactions between humpback whales and their prey in future years of this program. Together, these UAV studies represent an important step in understanding predator-prey dynamics within hotspots for foraging upper trophic level predators and will lead to critical insight into how fish distributions affect marine mammal distribution and potentially mortality events.

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Tel: 631-632-3187; Fax: 631-632-8820

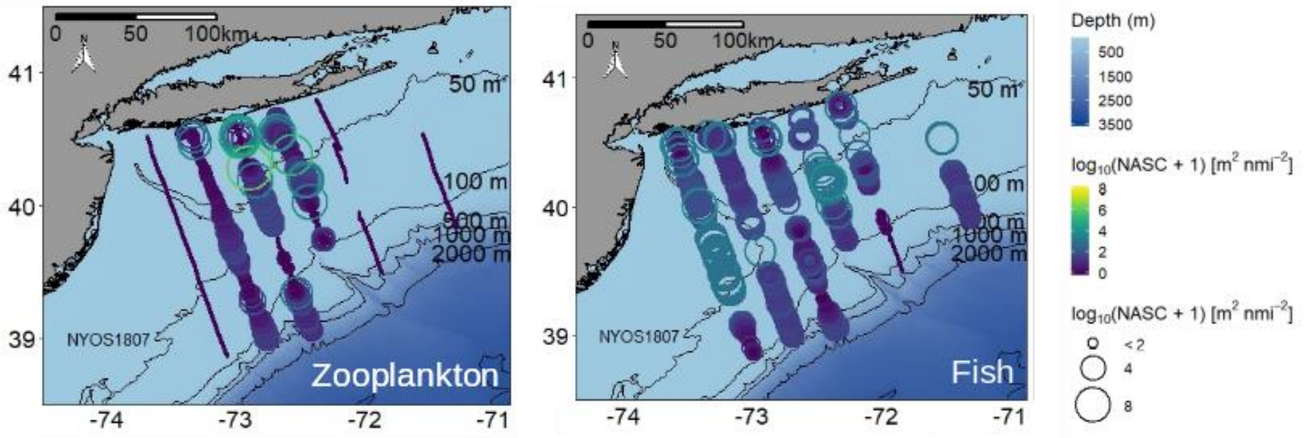

Figure 19. Multiple-frequency acoustics allows for the identification and discrimination of scattering from different trophic levels of the pelagic ecosystem. Preliminary analysis from the July 2018 cruise demonstrates that the distribution and abundance of zooplankton (primary consumers) and fish (secondary consumers) are different across the study region. This analysis will be refined by using catch data from the ring net and fish trawls to further discriminate among the many different types of pelagic organisms found in the New York Bight, as well as to integrate these results with physical processes affecting the lower trophic levels, and upper-trophic animals who feed on the fish.

Objective 7: Provide supplemental R/V Seawolf vessel staffing support

The offshore monitoring and survey projects covered within this agreement requires extensive use of the SoMAS R/V Seawolf. The increase in vessel operations is so significant that previous operating crew size was insufficient to meet the safety and programmatic needs of these field-intensive offshore projects. There is only one port (Shinnecock) on the south shore of Long Island that the Seawolf can enter and it can only enter around the high tide. Due to the lack of harbors, the Seawolf must operate round the clock for these projects in order to eliminate the transit times which were making the projects sampling schemes not viable. The goals for this objective are to hire additional crew to support the increased use and 24 hour operations necessary for the projects. The additional crew specified are one captain capable of running trawling operations and two deckhand technicians. The programs within this MOU require extensive use of commercial fishing gear. This is a very specific skill set which most mariners capable of operating the Seawolf do not possess. In September, we successfully recruited Michael Mason as captain with this skillset. Michael has extensive experience working on vessels the size of the Seawolf engaged in commercial bottom trawling, midwater trawling, surf clam dredging, and scalloping, as well as experience working on vessels engaged in scientific research. With Mike's addition we have three captains able to run trawling operations, and he is now rotating in for shifts, becoming acquainted with the DEC-funded research programs, and the teams of researchers. We are, hopefully, in the final stages of recruiting deckhands for this position and hope to have at least one person onboard before the start of sampling in February. It has proven difficult to secure a candidate due to the nature of the work involved and qualifications we are asking for.

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Tel: 631-632-3187; Fax: 631-632-8820

However, we will continue to meet the needs of these projects until we are able to secure the full complement of deckhands.

Summary of Accomplishments:

We have initiated and fully implemented an offshore sampling program that monitors the pelagic ecosystem of the New York Bight in just two short years. This included installing a completely new custom fit seawater system on the R/V Seawolf to allow us to take physio-chemical measurements while underway, purchasing a glider and implementing a sampling program, initiating a UAV program to examine whale body condition, and designing, constructing, and installing a state of the art sub-surface mount system for a four frequency fisheries echosounder transducer array.

With the initiation of the seasonal cruises and ocean glider program we have a much greater presence in the New York bight and more broadly in the Northeast US with planned glider deployments that would monitor conditions in just the NY Bight for a full third of the year where previously there was very little coverage at all. In addition, collaboration and coordination with other glider operators in the area has increased the data coverage of the Mid-Atlantic and broader Northeast US. There were five gliders deployed in the area during the fall, and, with NOAA support, we are adding to the parameters measured by the glider with the installation of a pH sensor for the summer cruise.

Within these varied aspects of the program, we have developed and standardized protocols and have trained field staff to collect samples and perform surveys for multiple objectives. We created a Data Management plan to store and share data with NYS DEC and to ensure the highest quality control standards for data as it is processed and analyzed.

Issues encountered during this period:

- A mixture of bad weather, staffing and boat repairs prevented us from completing all the cruises that were planned for the 2018-2019 period. All but two planned cruises were completed.
- Delays in hiring has delayed some of the indicators work (Objective 1) and sample processing (Objective 2,3).
- Our hiring strategy changed as we have encountered restrictions and difficulties in hiring half-time students and are unable to hire part time employees. As such, we hired 2 full-time technicians in the place of students and will evaluate personnel needs in the coming years as the scope of work is refined
- As part of Objective 6, we had planned to collect tissue from fishes and biopsy samples from marine mammals to conduct stable isotope analysis to understand food web interactions. However, we discovered that to take biopsy samples logistically is difficult to do from the R/V Seawolf and we have heard that efforts are underway by other teams in the NY Bight to do similar work. We are still collecting fish and invertebrate samples for stable isotope analysis to potentially inform these efforts later.

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Tel: 631-632-3187; Fax: 631-632-8820

Work planned for upcoming quarters:

Objective #	Activity/Deliverable	Timeframe
1	Complete indicator review	January 1, 2020
1-6	Complete 4 seasonal cruises	December 2020
2	Complete 4 seasonal glider missions	December 2020
2	Process water samples for carbonate chemistry	ongoing
3	Process zooplankton samples	ongoing
1-6	Provide data to the NYDEC	ongoing
1-6	Database development	ongoing
1	Submit at least one manuscript for peer-review on ocean indicators	June 2020
2	Submit at least one manuscript for peer-review on carbonate chemistry	June 2020
7	Complete hiring of 2 deckhands	June 2020

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Stony Brook University, Stony Brook, NY 11794-5000
Tel: 631-632-3187; Fax: 631-632-8820

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