Northern Shrimp Survey Mitigation Plan

I. Purpose of the survey

The Gulf of Maine (GoM) Northern Shrimp Survey is an annual, standardized fishery-independent trawl survey that started in 1983 (Clark et al. 1999) and has operated continuously on the *Gloria Michelle* with gear developed in partnership with the commercial fishing industry. It is the primary source of fishery-independent data used for the northern shrimp (*Pandalus borealis*) assessment.

Data collected at sea include trawl catch, gear performance monitoring, and environmental data. Catch data include total weight and individual lengths of all species captured at each station. A 2 kilogram (kg) subsample of Pandalid shrimp is collected at stations where the catch was greater than 2 kg to determine species composition. Northern shrimp are sorted by sex and maturity stage prior to weighing, and length frequency measurements are collected (mid-dorsal carapace length, rounded down to the nearest tenth of a millimeter) in addition to sex and female spawning condition (Rasmussen 1953; McCrary 1971). When less than 2 kg of shrimp are caught at a station, the entire catch is processed as described above. For other species of invertebrates and finfish, standard Northeast Fisheries Science Center (NEFSC) Bottom Trawl Survey (BTS) techniques (Azarovitz 1981; Grosslein 1969) are used to process the catch. Relevant lengths are measured for bony fishes, American lobsters (*Homarus americanus*), crabs, bivalves, and cephalopods. All species weights are recorded to the nearest 0.001 kg. Age structures are saved for a select number of finfish species, including Atlantic herring (*Clupea harengus*; frozen heads) and white hake (*Urophycis tenuis*; otoliths removed at sea). The remainder of the catch (e.g., miscellaneous invertebrates, trash) is recorded by weight. Total and individual weights and lengths for shrimp and all other measured species are recorded directly into the Fisheries Scientific Computer System (FSCS), version 2.0.

Gear performance and environmental data are collected using a microcat SBE37 and a suite of NOTUS net monitoring sensors. These sensors are deployed on the trawl during each tow to capture vertical profiles of temperature and salinity and net performance. Vessel instrumentation continuously collects depth, location, and various environmental measurements including wind speed, wind direction, and surface water temp.

In addition to the shrimp assessment, Northern Shrimp Survey data are used in assessments for 6 other species (longfin squid [*Doryteuthis pealeii*], Illex squid [*Illex illecebrosus*], Atlantic herring, witch flounder [*Glyptocephalus cynoglossus*], monkfish, and white hake) and could potentially be used in 4 others (lobster, jonah crab [*Cancer borealis*], red crab [*Chaceon quinquedens*], and pollock). The ongoing Atlantic States Marine Fisheries Commission (ASMFC) river herring (*Alosa pseudoharengus*) assessment will be using the alewife index from this survey, as well.

The primary users of Northern Shrimp Survey data are NEFSC assessment scientists, members of the ASMFC Northern Shrimp Technical Committee, and a variety of regional collaborators. The Northern Shrimp Survey is the only offshore GoM trawl survey conducted during the summer months.

A complicating factor for this survey is that the northern shrimp stock is at very low abundance. The fishery has been in moratorium for 10 years. However, the survey generates information important in multiple stock assessments even if shrimp remain at low

abundance. This survey also provides ecosystem data in the summertime in the GoM, which is a body of water warming at an almost unparalleled rate. Therefore, there is considerable value in keeping this survey operating as a summer ecosystem survey, recognizing the value of it being the only offshore GoM survey conducted during the summer months. Survey objectives include providing data for species assessments that currently use data from the Northern Shrimp Survey in addition to oceanographic and food web data. To mitigate impacts associated with offshore wind development, this survey would add acoustic data collection/analysis throughout the existing survey area, while still continuing with routine trawling with the shrimp net where feasible. Conductivity, temperature, and depth (CTD) sensor and zooplankton collection (e.g., bongo or optical methods) operations could be incorporated into the cruise plan. Inside the WEAs, the focus would be on acoustic data collection and biological sampling using a trawl net at fixed stations, baited cameras, or other fixed gear (e.g., shrimp pots).

II. Survey Details

Beginning Year: 1983

Frequency: Annual

Season: Summer (July/August)

Geographic Scope: Western Gulf of Maine

Platform(s): R/V *Gloria Michelle*

Statistical Design: Random Stratified

Methods: Trawl tows are conducted with a modified commercial shrimp trawl at randomly selected stations within each stratum. There are 12 strata for this survey, but stations are currently only plotted in 10. At each station, a 15-minute tow is made at a vessel speed of 2 knots. Gear consists of Bison size 7+ trawl doors and a 4-seam modified commercial shrimp trawl fished at a scope of 3:1 in depths up to and including 85 fathoms; 250 fathoms of wire in depths between 86 and 100 fathoms; and a scope of 2.5:1 in depths greater than 100 fathoms.

III. Effect of Four Impacts

1. **Preclusion** of NOAA Fisheries sampling platforms from the wind development area because of operational and safety limitations.

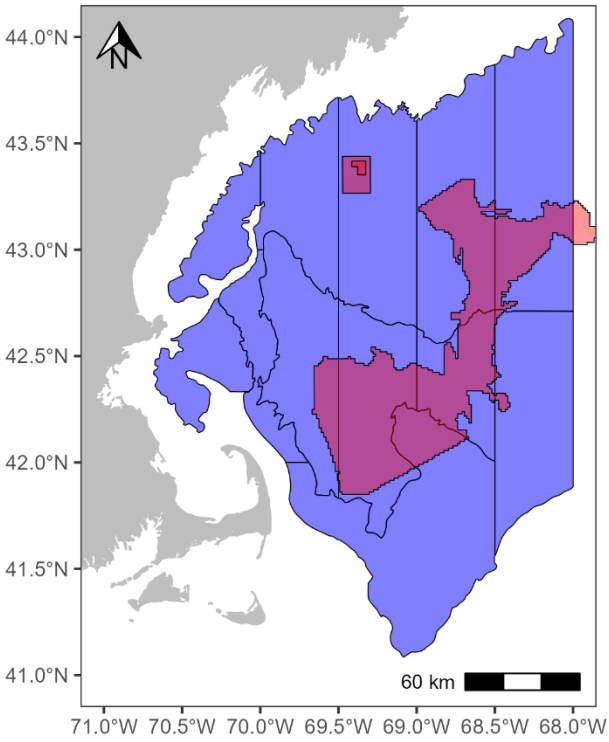
   The offshore wind footprint in the GoM is still uncertain, so the scale of impact of Wind Energy Areas (WEAs) on this survey is hard to determine. The type of anchoring system used for floating turbines has a large impact on the footprint of turbines, but in general, mobile fishing gear is unlikely to be used in areas where there are floating turbines. The cable infrastructure associated with floating turbines makes it too dangerous for trawling.

The *Gloria Michelle* may still be able to transit through the area, though this is not confirmed and may be weather-dependent. If a vessel or autonomous vehicle can operate through the WEA, sampling could be conducted using alternative technologies such as acoustics, optics, and fixed gear. The following mitigation plan assumes that a vessel (either the *Gloria Michelle* or an alternative vessel) would be able to enter the WEA to conduct acoustic surveys at a minimum.

2. **Impacts on the statistical design of surveys** (including random-stratified, fixed station, transect, opportunistic, and other designs), which are the basis for scientific assessments, advice, and analyses.

There are still many unknowns regarding the extent and type of wind infrastructure in the Gulf of Maine. It seems probable that the southern strata, which traditionally have low northern shrimp abundance and are less important to stock assessments, will be first to be impacted by wind development (Figure 1). It is possible that these stations could be dropped with little to no consequence on stock assessments for northern shrimp. This opens the possibility that WEAs can still be designed in a way to avoid impacts to this survey and reduce the need for mitigation for that specific stock assessment.

Figure 1.



Northern Shrimp strata shown in blue, wind planning area (as of March 2024) shown in red.

However, over the course of 30 years, WEAs may overlap with important strata. If mobile gear cannot sample in WEAs (thus impacting abundance estimates), and the survey moves or eliminates stations and/or relies on alternative technologies, the variance around estimates of abundance will change, altering the precision of stock assessments. If WEAs are installed in strata that are important to the stock assessment, it will increase the need to develop new shrimp sampling methods for use within the WEAs.

The Northern Shrimp Survey uses a stratified random sampling design. The standard trawl survey with stratified random sampling will not be possible within survey strata that include WEAs once they are developed, so new survey methods (e.g., acoustic, fixed gear), sampling designs (e.g., fixed stations, systematic transects), and statistical analysis will be needed to provide information on target species within WEAs.Trawl sampling can continue as is in strata unaffected by WEAs, but in order to make the entire survey coherent, new statistical designs might affect station location and number. Additionally, new sampling methods that are compatible with sampling within WEAs will be needed both inside and outside of strata affected by WEAs. These methods will need to be paired with the trawl sampling.

3. **Alteration of benthic and pelagic habitats and airspace** in and around the wind energy development, requiring new designs and methods to sample new habitats.

   We expect that the benthic habitat will be altered within the WEAs and that species distributions are likely to be impacted, however it is unclear how much the benthic habitat would be altered if the turbines are floating. *P. borealis* tend to prefer muddy habitats and are sensitive to temperature. The impacts of WEA-related habitat changes on shrimp may depend on where turbines are installed, the cable configuration, and the type of anchoring system used. In general, the amount of hard substrate and structure will likely increase. Changes in currents around wind infrastructure may also alter aggregation patterns of shrimp, highlighting the need to sample within WEAs using new methods to identify these potential changes.

4. **Reduced sampling productivity** caused by navigation impacts of wind energy infrastructure on aerial and vessel surveys.

   If the *Gloria Michelle* or an alternative vessel is unable to transit through the WEAs, there will be large impacts to sampling productivity. At this time, we don't know where the WEAs will be, the type of anchoring systems to be used, or the density of structures, so the impacts are difficult to assess. Additionally, it is likely that we would re-stratify if we move forward with a new survey design, and we would look to reduce any navigational impacts caused by WEAs in the new survey design. The following mitigation plan assumes that a vessel (either the *Gloria Michelle* or an alternative vessel) would be able to enter the WEA to conduct acoustic surveys at a minimum. Additional time would still be required to navigate around structures and locate suitable sites within WEAs.

IV. Mitigation Planned, as per Six Elements

1. ***Evaluation of survey designs***

   At this time, it is difficult to evaluate and quantify the impacts of WEAs because we do not know where the turbines will be located or what the turbine layout/design will look like. We are anticipating that these will be floating turbines and that they will be located within the southernmost Northern Shrimp Survey strata. We assume current strata will be valid in the short term, but we will need to pilot new methods and plan on restratification once the turbine layout is known.

   Once we know the exact footprint, the Northern Shrimp Technical Committee will need to analyze impacts of removing these areas from the survey. Similar analyses should be conducted by assessment scientists that rely on finfish, crab, and lobster data from the Northern Shrimp Survey. If it is determined that the presence of WEAs will significantly impact the scientific advice derived from our survey data, we should redesign the existing survey to a Summer Ecosystem Survey.

   Given the status of the Northern Shrimp Stock, the use of survey data in other species stock assessments, the survey's value in monitoring ecosystem change, and the likelihood of having constraints on operating mobile gear within WEAs and the resultant introduction of new survey methods, new survey designs will need to be developed.

2. *Identification and development of new survey approaches*

Depending on the density of turbines and anchoring systems used, it may be possible to trawl at fixed stations within WEAs. However, in the event that trawling cannot be done at all within WEAs, we recommend a survey that uses a combination of fixed gear and acoustics within WEAs, as well as trawling paired with acoustics outside of WEAs. Fixed gear would be used for biological sampling at fixed stations and not used in abundance estimates. It is not known how well acoustic survey methods will perform for groundfish and benthic invertebrates (e.g., lobster), so optical methods may also be used to gather abundance data for these species. This design needs further development in terms of how and where biological sampling with trawls and fixed gear would be accomplished. For fixed-gear stations, determining the specific gear to be used, including the potential value of optical methods, is still needed.

This survey should also incorporate CTDs and zooplankton sampling to enhance the survey's utility to multiple assessment groups. A new platform is not likely to be needed for trawling but may be needed for the additional methods being considered. The *Gloria Michelle* is a small vessel (68'), and so it should be able to transit the WEAs for acoustic transects but does not have the ability to deploy bongo nets for zooplankton capture or launch CTDs. It is possible that multiple vessels could be used to complete the survey (e.g., *Gloria Michelle* for trawling and a different vessel for everything else), or a new platform that could accomplish all sampling could be used. If the *Gloria Michelle* or similar vessel cannot transit or conduct acoustic transects within the WEAs, we may have to move to other solutions such as autonomous vehicles for acoustic transects (e.g.. DriX; more info here).

The design for a new survey should be developed by current NEFSC staff and a PhD-level biologist (contractor) in consultation with the Northern Shrimp Technical Committee. Staff from the Oceans and Climate Branch (OCB) and the Population Dynamics Branch (PDB) should provide feedback on what data products would be useful from the GoM in the summer. Pilot studies should be conducted to determine which combination of mobile and fixed gear would best achieve survey goals. We expect it should be possible to complete a uniform transect pattern with acoustics throughout the WEAs.

Simulations should be conducted to assess the impacts of dropped stations on assessments for shrimp and other species, as well as ways to incorporate fixed stations into assessments. The approach used by the Survey Simulation Experimentation and Evaluation Project (SSEEP) focused on the BTS, but it could be adapted for the Northern Shrimp Survey. It will be important to know which areas are the highest priority for sampling and how many stations per strata are needed to provide useful data if only trawl tows are conducted. It is likely that fixed stations will primarily be for biological sampling, though, and not abundance estimates, but it may be possible to do short tows in some fixed locations.

The current recommended redesign would focus on acoustic data collection/analysis throughout the Western GoM, while still continuing with routine trawling with the shrimp net paired with acoustics where feasible. CTD and zooplankton capture operations could be incorporated into the cruise plan. Inside the WEAs, the focus would be on acoustic data collection for abundance estimates and biological sampling with fixed gear

solutions. Fixed gear may also be useful for estimates of species that are not identifiable with acoustics. This design would require input from experts in active acoustics (Mike Jech and possibly additional staff), as well as from staff in PDB to ensure that acoustic data would be useful for the various assessments. This redesign would also require installation of new acoustic systems for the *Gloria Michelle*, including 38,120, 200, and 333 kHz.

Alternatively, if no vessels were allowed within WEAs, an uncrewed vessel with acoustics (e.g., DriX) could potentially still enter the area, but we would not be able to collect biological samples. If it is unsafe for even an uncrewed vessel to enter, we will be forced to estimate abundance within the WEAs based on perimeter stations or remove WEAs from assessments entirely. This would have the greatest impacts on the information provided to management and would not mitigate the survey impacts due to offshore wind.

3. ***Calibration and integration of new survey approaches***

Acoustic data will be used to link inside WEAs to outside WEAs as acoustic transects will be conducted in all strata. Integrating acoustic sampling and alternative methods of biological sampling (such as fixed gear) with the current trawl survey will require calibration and pilot studies to identify appropriate gear types. Additional staff will be needed (in particular, an acoustic data analyst), and new equipment will be needed for pilot studies and survey activities. Pilot studies will be used to determine how much information can be gathered from acoustics. Acoustic methods have been used to assess biomass, density, and size distribution of herring, krill, and other pelagic species (e.g., Jech and Sullivan 2014; Jech et al. 2018; Stevens et al. 2023), but it will be necessary to conduct feasibility studies to evaluate the effectiveness of acoustic methods to distinguish species of crustacea (e.g., shrimp vs. krill) and pelagic species (e.g., Atlantic vs. river herring). It is currently not clear how well the acoustic data can be translated to species abundance for groundfish species. Groundfish such as flatfish, skates, and rays will be very difficult to even detect, much less enumerate, with acoustic methods, but demersal species such as Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) have been assessed using acoustic methods. Continuing advances in acoustic data analysis will enhance the utility of this method over time, and this process will be more efficient and effective with additional acoustic expertise.

Trawls and acoustic transects of the same areas should be conducted to ground truth acoustic surveys. Conducting “before” surveys within WEAs using both the current and new methods will help determine how important it is to sample those areas. Having good baseline data using both the traditional trawl alongside acoustic and fixed gear data will allow integration of the datasets and planning for future surveys.

If fixed gear (e.g., baited camera stations, shrimp pots) is only to be used for biological sampling within WEAs, it would not need calibration. However, it is possible that alternative gears could provide a “trawl equivalent” sample for certain species. Pilot studies should be conducted comparing different types of fixed gear to trawling to determine the feasibility of this approach.

The challenge of integrating multiple data sources will depend largely on how well the various methods agree with each other, and the amount of variation within each method.

Ideally, the acoustic data and trawl data will be in agreement outside the WEAs, and fixed-gear methods can help provide a “check” for acoustic data within WEAs. If methods are not in agreement, stock assessment biologists will have to make more adjustments to models in order to accommodate different data sources with different amounts of variability.

Oceanographic (CTD) and zooplankton sampling should be added in all areas and would be new for this survey. As these methods would be new to this survey, they would not require calibration unless integration with sampling on other vessels (such as the BTS) is desired. The amount of station coverage needed for these methods will be determined with input from the OCB.

4. ***Development of interim provisional survey indices***

Data from the Fall BTS and spring Maine Department of Marine Resources survey can be used as interim indices for the Northern Shrimp Survey.

Current assessment models receive input from trawling data, so they may need to be modified to accommodate inputs from acoustic surveys and other new methods. These modifications may vary depending on the stock in question. Calibration studies should allow acoustic data to be integrated into the existing time series more easily, but if that is not possible, WEAs will be treated separately from areas outside the WEA and a new time series will be created.

5. ***Wind energy monitoring to fill regional scientific survey data needs***

It is currently unknown what monitoring wind energy developers will do in the GoM. If developers are collecting data at a time and in locations consistent with our Northern Shrimp Survey needs, generating equivalent data, and conducting data collection over the lifetime of the development, there could be opportunities to mitigate impacts to the Northern Shrimp Survey.

Collecting pre-construction data using acoustics, fixed gear, and trawling in WEAs will be important to determine how northern shrimp distributions may change with construction. Once turbines are in place, we may need to adjust station selection (switch from stratified random to fixed stations) and restratify in response to gradients of organisms among turbines, how close the turbines are to each other, and cable location.

Use of acoustic survey methods will be instrumental for monitoring within the WEAs. If acoustic surveys are successful at identifying abundance and distribution of shrimp and other species typically assessed in the summer survey and we can conduct biological sampling with fixed gear, we will mitigate many of the largest impacts on the collection of northern shrimp abundance information. However, it is currently not known how much trawling will be impacted or how well acoustic survey methods will perform for other pelagic species, and benthic species, in particular, will be difficult to assess with acoustic methods. Assuming a vessel is able to enter the WEAs, the areas would be monitored annually using acoustics and fixed gear methods. Optical methods may also be used to gather abundance data for groundfish, lobster, and crab. Biological sampling could be done using fixed gear at fixed stations.

Alternatively, if no vessels were allowed within WEAs, an uncrewed vessel with acoustics (e.g., DriX) could potentially still enter the area, but we would not be able to collect biological samples. If it was unsafe for even an uncrewed vessel to enter, we will be forced to estimate abundance within the WEAs based on perimeter stations or remove WEAs from assessments entirely. This would have the greatest impacts on the information provided to management and would not mitigate the survey impacts due to offshore wind.

6. ***Development and communication of new regional data streams***

Any changes to the design of the Northern Shrimp Survey will first need to be communicated internally to the NEFSC and then to the ASMFC. The Northern Shrimp Technical Committee of the ASMFC can then determine how best to communicate the changes to industry and other stakeholders, which will probably be a public meeting.

As we will likely be generating a lot of acoustic data, we will need to formulate a plan for how best to manage, store, and serve the information. Active acoustic data will be archived at NOAA's National Center for Environmental Information (NCEI) and available via the cloud (currently, this is through Amazon Web Services), but there is still a need for local data management, and it is likely that we will need to purchase and set up the infrastructure required to adequately meet our needs.

V. Proposed Schedule for Implementation

Element	Task	Activities	Milestone
V. 1. & 2.	-Plan to exclude WEAs from trawl survey, assess impacts -Plan to survey WEAs using acoustics and fixed gear	-Prepare logistics for potential dropped stations in WEAs -Prepare logistics for vessel change, acoustic survey, fixed-gear pilot studies	-Complete pilot studies, identify new gear and acoustics methods -Conduct surveys when WEAs are completed
V. 3.	-Conduct "before" surveys of WEAs and perimeters if deemed necessary -Perform calibration studies on new vessel, fixed gear, acoustic methods	-Prepare logistics to conduct "before" surveys of WEAs -Prepare for calibration of new gear	-Collect data in WEAs and perimeters prior to construction -Complete calibration of new gear
V. 4 & 5	- Produce survey indices using acoustics data and fixed gear data, with potential fixed and/or dropped stations	-Implement results of analyses to ensure consistent data products	-Provide data sets and indices to management and assessments
V. 6	-Collaborate with Northern Shrimp technical committee, industry representatives, NEFSC staff, and ASMFC staff to make necessary changes	-Conduct collaborative meetings and continue participation with partners	-Inform all collaborators of changes. -Inform all stakeholders of changes

VI. Links to Other Surveys

There are shared data storage needs with groups that are collecting acoustic and optical data (such as the Protected Species Division and Passive and Active Acoustics branches). There has been discussion of possibly sharing servers for storage and processing with these groups. The Passive Acoustic Monitoring survey has similar needs for data management, analysis, volume storage, and processing.

There are linkages to the BTS in terms of survey methods and data collected, so changes to survey design are being discussed with them. An acoustic survey can also identify certain finfish (e.g., herring), which could be of use to other surveys that are not able to sample within WEAs, such as the BTS. Similar approaches for sampling in WEAs (such as fixed stations and fixed sampling gear) may be used. Information acquired in the future about areas that are unsafe to fish/sample will be shared among groups, but as the surveys use different methods, there will still be unknowns for each individual survey.

The GoM Bottom Longline Survey may be working in overlapping areas, so information will be shared about the locations of wind infrastructure and the safety of operating in WEAs.

VII. Adaptive Management Considerations/ Opportunities

There are many unknowns about the final siting and design of wind structures, especially floating wind turbines. Expansion of WEAs or increased density of turbines and cables will require additional adjustments to survey strata or sampling intensity/design. Changes in the status of northern shrimp will also require adjustments to plans. Shifts in shrimp distribution in response to wind turbines may likely warrant changes to strata placement in the future to best capture distributions, as well as changes to gear used. Survey staff will continue to work with the Northern Shrimp Technical Committee (ASMFC) to monitor the status of northern shrimp and WEA development, and will revise survey design and analytical approaches as needed.

Future developments of acoustic technologies could lead to collection of data on additional species abundance and distribution, which would enhance the value of the survey and further integration with other surveys, such as the BTS.

VIII. Statement of Peer-Review Plans

The proposed changes to the survey (especially the addition of acoustics and fixed gear) will first be reviewed by the Survey Mitigation Wind Working group. The review process would then extend to the Northern Shrimp Technical Committee (ASMFC) and appropriate Population Dynamics staff.

IX. Performance Metrics

Currently, data quality is assessed based on the completeness of the survey (e.g., number of stations/strata completed). Using acoustics instead of trawling may lead to higher

variability in estimates from within WEAs. The coefficient of variance (CV) around estimates of abundance is used in stock assessments. The impact of integrating multiple data sources on CV will depend on how well the various methods agree with each other and the variation within each method.

Sensitivity analyses could assess the uncertainty that results from not sampling in an area, as well as the impacts of increased CV. Simulations should be conducted to determine how much assessments change when a WEA is sampled or excluded. Simulations could also assess the impacts of high variance in each of the data sources.

X. References

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