Marine Mammal & Sea Turtle Vessel (Turtle Ecology) Survey Mitigation Plan

I. Purpose of the survey

To date, the Northeast Fisheries Science Center (NEFSC) Turtle Ecology (TE) surveys have involved a wide variety of sampling platforms (NOAA ships, contracted ships, small boats, as well as various aircraft including drones) and techniques (e.g., satellite tagging, camera tagging, tissue sampling, morphometrics). These diverse efforts aim to expand our knowledge of sea turtle ecology by targeting and sampling individual organisms. The primary goal of this survey is to tag and biologically sample sea turtles to inform our understanding of their biology, distribution, and habitat such that we can advise management as to the impacts from various anthropogenic potential threats. This approach differs substantially from line transect surveys (included in other chapters of this survey mitigation plan) that seek mainly to enumerate the animals within a sampling unit. The TE data collection program is placed in the "survey" context because it is a long-running field program that collects data on species that have federal mandates for data collection with the National Marine Fisheries Service (NMFS) listed as the trust agency, and the resulting data are stored at the NEFSC in Oracle databases and used for science and management applications.

A vast array of information is collected on TE surveys (Table 1) and used in a variety of science products. This research has supported a variety of fishery management plans, either through direct citations within a Fisheries Management Council management plan (such as satellite tag locations used in Sea Scallop Framework 21), or through inclusion as Terms and Conditions (T&C) or Conservation Recommendations within the Section 7 Biological Opinions for multiple Fishery Management Plans. For example, the Lobster, Scallop, and Batched Fisheries Biological Opinions include a call for studies on sea turtle distribution, behavioral studies to improve understanding of interactions with fishing gear, and foraging studies as well as studies and analysis necessary to develop population estimates. The Sea Scallop Biological Opinion includes a non-discretionary requirement to use appropriate technologies (such as satellite tagging) to better determine whether turtles are encountering gear while they are on the bottom or in the water column.

In addition to supporting the management of commercial fisheries, data products from TE surveys are critical inputs into sea turtle risk assessments and abundance estimates. Data from satellite tagging surveys are used to assess seasonal patterns of sea turtle distribution (Winton et al. 2018) and are combined with climate data to project future shifts in turtle habitat due to climate change (Patel et al. 2021).

Sea turtle dive and surfacing data obtained from TE cruises are critical inputs into abundance estimates calculated (by the Navy and NOAA) based on line transect survey data. Distance sampling and density surface modeling are commonly used approaches for estimating animal density and abundance (Buckland et al. 2001, Miller et al. 2013). When turtles are not available to be seen (e.g., because they are submerged or otherwise out of the observer's field of view; Laake et al. 1997), then density and abundance will be underestimated. This bias in density and abundance estimates is known as availability bias. Because of their need to thermoregulate, sea turtles have complicated patterns of availability (likely more complicated than other marine vertebrates), and availability bias can have order of magnitude effects on the abundance estimates. The behavioral data collected on TE surveys address this critically important source of bias.

Table 1. Types of data and samples collected on turtle ecology cruises.

Morphological	Weight
	Carapace length measurements (6 metrics)
	Body depth (which can be used to assess health)
	Tail measurements (2 metrics, to aid in assessing sex and maturity)
Physiological	Body temperature
	Electrocardiogram (EKG)
	Ultrasound
Tissue Samples	Blood, skin, scute, cloacal contents (genetic analysis, sex determination, blood biochemistry, and hematology)
Oceanographic	Temperature upcasts (12 pressure-temperature coordinate pairs) on selected deep dives
Identifying Tags	Flipper, Passive Integrated Transponder
Behavioral	Dive profiles, percent time at surface, location information, predator-prey information

Sea turtles represent the Endangered Species Act (ESA) taxa expected to have the most numerous interactions with wind development in the Greater Atlantic region (GAR), but our understanding of turtle-wind interactions is limited. One reason for this is that studies designed to target broad groups of taxa or other protected species sometimes fail to provide enough turtle information to be useful. In addition, sea turtles are the protected species taxa with the least amount of existing data with respect to wind development impacts because most operational wind developments (across the globe) are in areas where there are no significant sea turtle aggregations. As a result, there is almost no impact data available for turtle taxa. The extremely low level of background knowledge increases the risks because uncertainty is large.

Historically, much of the focus on sea turtles has been on the nesting beaches and coastal waters surrounding the Southeast (SE) U.S. More contemporary research has revealed that several species of sea turtles seasonally occupy the continental shelf waters in the GAR. Perhaps due to climate change, the U.S. Mid-Atlantic has been identified as a globally important foraging ground for loggerhead sea turtles (Northwest Atlantic [NWA] Distinct Population Segment [DPS]). Hundreds of thousands of sea turtles are expected to have at least thousands of interactions with anthropogenic activities in the GAR every year. Despite relatively high population sizes, all sea turtle species are still classified as Threatened or Endangered because of continued threats that curtail recovery. The NWA leatherback (*Dermochelys coriacea*) population (ESA status = Endangered) has a decreasing nest trend and high extinction risk. The previous increase in Kemp's ridley (*Lepidochelys kempii*) nest numbers has ceased, and the species now (ESA status = Endangered) has an uncertain population trajectory and is data deficient in the Atlantic. The Northern recovery unit of the NWA loggerhead (*Caretta caretta*) DPS (ESA status = Threatened) is vulnerable because of lower nesting numbers compared to more southerly nesting assemblages). The North Atlantic DPS (ESA status = Threatened) is also found throughout the GAR. This juxtaposition of high conservation concern (as evidenced by ESA status) and high number of expected interactions make turtles a priority species with respect to conservation research.

The NEFSC has conducted dedicated TE surveys and has also coupled turtle ecology studies with other surveys such as the Atlantic Marine Assessment Program for Protected Species (AMAPPS) and the National Centers for Coastal Ocean Science (NCCOS) surveys. As a result of the TE studies, we now know more about turtle behavior on Mid-Atlantic foraging grounds (Patel et al. 2016); loggerhead use of the water column and ability to carry instruments to collect oceanographic data (Patel et al. 2018); loggerhead distribution and the importance of the Mid-Atlantic bight as a turtle foraging ground (Winton et al. 2018); biochemistry and hematology of migrating turtles (Yang et al. 2019); shifts in sea turtle behavior and distribution during an ecosystem-level perturbation (Crowe et al. 2020); the risk of gas embolism in sea turtles during routine dives (Robinson et al. 2021); the probability of turtle habitat to expand seasonally and geographically (Patel et al. 2021); and the complex patterns of sea turtle surface availability (Hatch et al. 2022).

II. Survey Details

Beginning Year: 2010

Frequency: At least once annually (except for 2020)

Season: Has covered most months except November, December, January

Geographic Scope: From North Carolina through the Scotian Shelf

Platform(s):
R/V *Henry Bigelow*, R/V *Selkie*, R/V *Coriacea*, chartered vessels (M/V *Warren* Jr, M/V *Scarlett Isabella*), and collaborative fishing vessels (F/V *Kathy Ann* and F/V *Ms Manya*), as well as various NOAA and chartered aircraft (for spotting turtles)

Statistical Design: There is not a single defined statistical design for the TE Survey because a vast array of methods are used. In an ideal situation, tags would be placed on randomly selected individuals. As this is impracticable, we try to approximate random sampling in realistic conditions by finding time-area strata where initial tagging bias is minimal, where the turtle density is high enough to facilitate tagging, and where the size class distribution of turtles is representative of the larger GAR. The species and sample sizes vary each year in response to source and availability of funds.

Methods: With regard to satellite tagging to produce estimates of surface availability to visual observers, we primarily capture turtles offshore during periods of expected movement or migration. We capture loggerhead turtles in the Mid-Atlantic either by the use of a large dip net from a small inflatable boat, during controlled testing of experimental fishing gear (trawl and gillnet) aboard a commercial fishing boat, or (more rarely) via stationary nets targeting turtles off of North Carolina. Dip net captures in the Mid-Atlantic can occur between May and September (though we expect high tagging bias from mid-June through September), while the North Carolina gear captures occur in late winter or early spring off of North Carolina. Leatherbacks are captured off the coasts of Massachusetts and North Carolina, aided by spotter planes, using a 2-m breakaway hoop net as described in Sasso et al. (2021). Upon a successful capture, turtles are equipped with satellite-linked transmitters (Wildlife Computers MK-10AF) via a tether attached to the caudal peduncle (SEFSC 2008).

III. Effect of Four Impacts

To our knowledge, there have been no studies describing the effects of construction and operation of wind energy developments on sea turtles. This may be because most existing large-scale wind energy areas (WEAs) are in cooler waters which do not host large aggregations of sea turtles. The life history and behavioral ecology of ectothermic sea turtles differs substantially from other marine taxa (such as marine mammals) that have already been studied in relation to wind development. Although the precise wind development impacts to sea turtle ecology is uncertain, the impacts on existing sea turtle ecology survey work is expected to be significant. The proposed wind development areas are expected to overlap very substantially with areas important to both turtle foraging and population monitoring. Tens of thousands of turtles are expected to be in areas where wind development will impact surveys. Hence, substantial effort will need to be invested if we are to understand and eventually mitigate impacts to our ability to survey turtles in wind development areas.

The most significant impact of wind development on TE surveys is that wind development is expected to alter sea turtle dive and surfacing behaviors, making existing sea turtle availability bias estimates obsolete. Data defining these behaviors are used to develop availability bias estimates which are foundational elements of abundance estimates. The 4 major impacts on surveys are described below.

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

   TE surveys are expected to be impacted by preclusion. As with other aerial efforts, the height of the turbine blades will preclude TE survey spotter planes from flying at lower altitudes in wind development areas. TE spotter planes are often used to locate turtles (particularly leatherback turtles) for capture or sampling. Typically, these planes fly at an altitude of 750’. Increasing the flight altitude (likely doubling it) would substantially decrease the likelihood of locating turtles and observing them subsurface in order to direct the capture boat to the turtle’s location prior to the turtle surfacing. If the structure of the wind turbines attracts or aggregates turtles, then areas where turtles are in sufficient density to be reliably captured may only occur in very close proximity to the turbines. The turbine structure that may attract the turtles may also preclude researchers from direct proximity to the turbines, which may make turtles unreachable using current techniques. Given these complexities, it is not currently well understood what preclusion will mean for TE surveys.

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.

   Although there are a wide variety of TE survey data that are useful for management purposes, the most sought-after data and data products are those which can be used to correct availability bias errors in analyses that produce abundance, density, and distribution estimates from behavioral data (such as data from satellite tags). Ideally, the same basic principles for tag deployment can be relied upon going forward: reduce bias from initial tagging location, operate in densities high enough to make tagging feasible, and target representative size class distribution. If there are new strata (or covariates) that affect sea turtle surface behavior or other aspects of sightability, then additional tags may need to be deployed across those new strata (or covariates). In addition to providing data to correct availability bias, the satellite tag data can be used to explore the potential use of new turtle habitats as well as changes in use of existing habitats.

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.

   Potential alteration of benthic and pelagic habitats include increased vessel activity; acoustic disturbance (from pile driving, vessel operations, and turbine function); electromagnetic field (EMF) effects from underwater cables linking turbines and distributing electricity to shore; potential increase in invertebrate fouling organisms that may create reef effects or create changes in prey distribution; changes in fishing that may affect the distribution of fishing discards that turtles prey upon; potential changes in water column stratification and thermocline; and in some areas, possible discharge of warm water effluent.

   Although the exact responses to these habitat alterations are not known, sea turtles are known to change behavior in response to oceanographic disturbance (Crowe et al. 2020). Potential sea turtle reaction to these alterations in the physical environment include displacement from WEAs; attraction to WEAs; changes in or disruption to critical behaviors such as foraging and migration; elevation of stress hormone levels and subsequent changes in behavior; changes in geographic and vertical distribution and density; and disruption in navigation abilities and subsequent changes in foraging and migration. Knowing the magnitude and spatial scope of wind energy attractant or deterrent properties is an essential component of interpreting future line transect survey results, and it obviously intersects with the preclusion and sampling efficiency issues.

   The most significant impact of wind development is that it is expected to make existing availability bias estimates obsolete and will therefore necessitate additional data collection. The existing estimates will become obsolete when the alteration of habitat changes turtle behavior. For example, in the summertime, loggerhead sea turtles spend considerably more time at the surface when they are in the Mid-Atlantic Bight compared to the Southeast U.S. Shelf (Hatch et al. 2022). We hypothesize that this is because loggerheads in the Mid-Atlantic Bight are primarily foraging on benthic prey, and because the water column is highly stratified, the bottom water is so cold that turtles are at risk of cold-stunning (lethargy or paralysis). To warm their core temperature, the loggerheads then bask at the surface for long durations. We also hypothesize that leatherback surface behavior is related to foraging on gelatinous zooplankton, and the pattern of plankton distribution and availability may be affected by WEAs (NASEM 2023). If water column stratification and prey distribution change, we would expect possible changes in sea turtle surface behavior patterns.

Because the alteration of benthic and pelagic habitats caused by proposed wind development may affect both water column stratification and the availability of sea turtle prey (including the relative importance of benthic versus pelagic prey), it is not justifiable to assume that behavioral data collected in absence of wind development could be applied to times and areas impacted by wind development. Hence the first step in mitigation should be the continued collection of behavioral data in both wind development areas and outside of wind development areas so that changes in availability bias can be explored and more informed decisions can be made about the stability of availability bias in the face of a changing environment. It is not currently known how far afield behavioral changes may manifest in terms of spatial distance from an impacted area.

In summary, the structures associated with wind development cause our current estimates of surface availability to be unreliable (which means we don't have a good way to translate future turtle counts into abundance estimates). This issue is particularly important because availability bias estimates are likely to be more complicated for sea turtles than for other species, can cause abundance estimates to differ by an order of magnitude, and are likely affected by water column stratification and prey availability.

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

   There are 3 main ways that we expect wind development may decrease sampling productivity of TE surveys;

   1. If it is necessary to sample turtles within WEAs, the increased flight height may make the use of spotter planes much less efficient given the increased difficulty of seeing smaller or submerged turtles at a higher altitude, and the increased flight height may also result in less efficient flights if low and mid-altitude clouds interfere with visibility.
   2. If WEAs change the movement patterns of turtles, it may increase the number of tagging surveys that are required, particularly if turtles do not move randomly between WEAs and undeveloped areas.
   3. If wind energy development increases competition for survey platforms, it may leave TE surveys with increased costs for platforms and/or sub-optimal survey platforms which could decrease survey efficiency.

IV. Mitigation Planned, as per Six Elements

1. *Evaluation of survey designs*

To pursue availability and habitat-based objectives, we need the following resources: shiptime, analytic and seagoing labor, database management, satellite tags, and associated equipment and supplies. For TE Surveys, our main survey designs involve catching, sampling, and tagging turtles in a way that approximates random sampling. If random sampling assumptions are violated, additional data would need to be collected to address the population structure or an alternative sampling scenario. Our overall approach would involve fieldwork and analysis that assess survey design and the impact of offshore wind development on scientific advice provided to management, specifically addressing the following questions:

- Do WEAs invalidate existing (pre-construction) availability correction factors by changing the way animals use surface waters?
  - This would be evaluated by comparing pre-, during, and post-construction surface behavior derived from animal-borne data loggers.
- Do WEAs change the geographic distribution of sea turtles in a way that necessitates tagging within WEAs or disrupts turtle movement or size segregation between WEAs and undeveloped areas?
  - This would be evaluated by comparing pre- and post-construction movement and distribution patterns derived from animal-borne data loggers.

2. *Identification and development of new survey approaches*

Because wind development is expected to substantially impact turtle monitoring and because Passive Acoustic Monitoring (PAM) solutions (which are successful for mammals) are not expected to work for turtles, we propose increasing satellite tagging and targeted suction cup tagging surveys as a way to mitigate expected complications due to development in WEAs. A key challenge is that our current capture methodology—spotting with airplanes and dip netting the turtles—may be adversely impacted by the turbines. We anticipate that we will try to spot and capture near turbines, and if the methods do not work, then we will have to explore new areas where we could capture the turtles for tagging. As part of this step, simulations and other analytic work should be done to identify sampling designs and sample sizes needed for each sea turtle species.

3. *Calibration and integration of new survey approaches*

As availability bias is expected to be of central concern, these data should be collected on an ongoing basis through baseline, development, and operational phases.The cost estimates below reflect expected costs for tagging 1 species per year.

For TE surveys, calibration of satellite tag data means using the study designs established in component 2 (Identify and Develop New Survey Approaches) to collect the necessary behavioral data. Data collection should be continuous throughout the baseline period, during construction, and during operational phases. Calibration of alternative monitoring techniques would involve multiple field trials of the new techniques then simultaneously implementing and comparing the new and old methods. For planning and budgeting purposes, this component can be rolled into component 5 (Annual Wind Energy Monitoring).

No formal calibrations of increased flying altitudes would be necessary as sightings data are not used in a quantitative way within TE surveys.

4. *Development of interim provisional survey indices*

N/A

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

For TE surveys, wind energy monitoring includes shiptime, analytic and seagoing labor, database management, satellite tags, and associated equipment and supplies. Although many needs have been discussed in this plan, the priority recommendation is to implement an annual TE survey to address availability bias and turtle distribution data needs and, if possible, to make a small amount of progress on associated issues. This would entail having a 3-week TE Survey cruise.

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

Data management for TE Surveys is complex because so many data sources and partners are involved. Currently, data management of both NEFSC and partner data are maintained in an Oracle Database with an accompanying data dictionary. This has been an efficient way for the Center to act as a regional hub to combine data from various sources. Currently, our TE database holds data which have been collected by or shared with the NEFSC, the Southeast Fisheries Science Center, Coonamessett Farm Foundation, the Virginia Aquarium and Marine Science Center, Fisheries and Oceans Canada, and the North Carolina Renewable Ocean Energy Program (Coastal Studies Institute). Database staff and equipment are needed so that we will be able to accept and consolidate future TE Survey data collections by partners such as states, nongovernmental organizations (NGOs), and developers.

V. Proposed Schedule for Implementation

The following proposed implementation steps are associated with the only applicable elements from Section IV (Mitigation Planned, as per Six Elements) that apply to TE:

1. Evaluate Survey Designs

- Hire full-time equivalent (FTE) employee who will work across all years and all components (Year 1)
- Collect data to be used for evaluation (Years 1-3)
    - 3-week TE Survey cruise per year
    - 20 satellite tags deployed per year on a single species
- Complete quantitative analysis and produce peer-reviewed manuscript (Years 3-4)

2. Identify and Develop New Survey Approaches

- With support from a contracted analyst, propose new sampling plan and publish peer-reviewed manuscript (Years 4 and 5)

5. Annual Wind Energy Monitoring

- Continue data collection (Years 4-30)
- Produce peer-reviewed manuscript at least every other year (Years 5-30)

6. Develop and Communicate New Regional Data Streams

- Archive data from this initiative (Years 1-30)
- Accession data and samples from other cooperators (Years 2-30)
- Roll out sharing approach (Year 5)
- Serve data to the public (Years 5-30); data may be shared earlier of course, but automated sharing approaches should be in place by the end of Year 5

VI. Links to Other Surveys

TE Surveys share many methodologies with other protected species vessel surveys, particularly the annual (typically in May) Right Whale Ecology cruise and the more infrequent Deep Diver Ecology cruises. We use the same small boats with similar requirements for superstructures (like bow pulpits and elevated sighting platforms), and we approach marine protected species in the water. We all use similar research ships to launch and recover the small boats. We both use aircraft for spotting our target species, and we often have aerial observers who simultaneously record sea turtle and marine mammal locations. We share field staff, and we collect tissue samples, take photographs for identification, use satellite and archival tags and associated equipment. We often both collect oceanographic data (which also links us to the EcoMon cruises), and we all accumulate large datasets of biological and behavioral data, which we use to produce scientific manuscripts for peer review.

TE Surveys also link to the eDNA Omics survey mitigation plan. The Turtle Ecology team has partnered with academics and NGOs to explore the potential of using eDNA to assess seasonal and spatial presence of sea turtles in nearshore and offshore waters. The University of Massachusetts-Amherst team has designed species-specific quantitative polymerase chain reaction (qPCR) assays for 2 sea turtle species and has validated the approach using tissue-derived DNA from target and non-target sea turtle species. The collaborative group has now taken water samples on multiple nearshore and offshore TE surveys and has plans in place to expand the research to include 2 additional sea turtle species along with additional survey transects.

The TE Survey shares several taxonomic and data connections to the MM&ST Vessel Abundance Surveys as well as the MM&ST Aerial Abundance Surveys. The data collected and analyzed by the TE survey group provides the availability bias corrections that are then used by the abundance surveys so estimates of turtles on the surface can be translated into estimates of turtles throughout the water column.

Impacts to aerial abundance surveys could have downstream impacts on the TE Survey if decreasing detection probabilities result in the need for additional satellite tagging and vessel-based survey activities to provide additional distribution and abundance information. If wind development increases the altitude of line transect surveys, and if the relatively small size of turtles precludes them from being detected at higher altitudes, then TE surveys may need to provide additional information on turtle distribution and abundance. In other words, if wind development precludes line transect surveys from effectively monitoring sea turtle distribution and abundance, then additional data obtained from TE Surveys may be required. Changes to aerial survey protocols may disproportionately affect turtles because (as a taxonomic group) they are harder to detect than cetaceans. Sea turtle taxa tend to have smaller group sizes than cetaceans, smaller visual cues (for example, no whale blows), and smaller body sizes. If traditional line transect surveys (detailed in the MM&ST Aerial chapter) flown at higher altitudes in WEAs are not effective for detecting small sea turtles, are there Turtle Ecology data streams (like eDNA monitoring, camera traps, or drone surveys) that could be used to fill the gaps?

It may also be necessary to develop additional alternative monitoring methods for sea turtles if line transect surveys (in other chapters) are not suitable. Possibilities for alternative monitoring include dedicated drone surveys at 400' and below, eDNA monitoring to augment visual surveys, and camera traps (above and below water, paired with AI analysis), but these costs are not included in the budget because it is not yet known if these will be necessary or if they would fall under the Turtle Ecology plan.

VII. Adaptive Management Considerations/ Opportunities

It would be ideal to revisit the plan every other or every third year so that adaptive management considerations and changes to survey approaches can be considered, including alternative data collection approaches.

VIII. Statement of Peer-Review Plans

In order to maximize the quality of the science, ensure the results are publicly available, and provide a record of the scientific progress, the availability bias products (and analytics steps required to produce the products) will be submitted to scientific journals with peer-review processes.

IX. Performance Metrics

Possible Performance Metrics
Number of tags per species per year
Number of behavior records per tag
Spatial-temporal distribution of behavior records

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