1. Title:

Whales and wind: Using satellite telemetry to estimate the habitat use and behavior of fin and humpback whales off southern NJ to understand the potential impacts of offshore wind development.

2. Investigator(s) name(s) and institution(s)

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3. Motivation/Objective

The New Jersey Research and Monitoring Initiative (RMI) has established priorities with regards to whales and offshore wind, including estimating their habitat use and distribution, understanding the environmental variables that drive these patterns, and evaluating the potential impacts from offshore wind on whale ecology. To accomplish these goals, an accurate baseline of ecological data is required before construction and operation begins. **The objective of this proposal is to fill this baseline knowledge gap through the use of satellite tagging of fin and humpback whales to better understand their habitat use and behavior in the region during the preconstruction phase of offshore wind development.**

Data gaps and research needs related to whales and offshore wind have been/are being developed by various entities and closely align with the priorities identified by the RMI. For example, the Regional Wildlife Science Collaborative (RWSC) Draft Science Plan recommends enhanced data collection on whale abundance, behavior, habitat use, and movement patterns to support detecting and quantifying changes in whale populations and distributions resulting from offshore wind and climate change. Additional recommendations in the Draft Science Plan include understanding the environmental context around whale habitat use, determining causality (natural and/or anthropogenic) for observed changes in wildlife and habitats, and identifying whether wind structures displace or attract marine mammals.

Offshore wind lease areas along the East coast of the United States may be located in habitats historically used by whales for migration and/or foraging. Therefore, it is important to understand how whales may interact with offshore wind farms during their seasonal movements and if avoidance or displacement during construction and operation results in altered behavior, migration routes, or foraging opportunities (Braithwaite et al. 2015; Kraus et al. 2019; Ljungblad et al. 1988, Richardson et al. 1990; Richardson et al. 1999; Ruppel et al. 2023). Whales located near wind farms may experience some behavioral and physiological stresses, however, there is currently no scientific evidence that noise from offshore wind site characterization surveys have led to the mortality of any large whales (NOAA Fisheries). Understanding the baseline preconstruction movement and behavior of whale species will provide critical data for avoiding, minimizing, and mitigating potential impacts to whales from offshore wind-related changes in marine soundscapes and habitat availability.

Southern New Jersey is located within the New York Bight, part of the United States mid-Atlantic (USMA), and seven species of large whale have been documented in the region (Hayes et al. 2020). A survey conducted in southern New Jersey in 2008 and 2009 found that fin whales (currently listed as endangered) were the most common species documented in the region (Whitt et al. 2015), although very little is known about the overall importance of this area to fin whales. For example, it is unknown if the area is consistently used for feeding by certain individuals, or if it is used in a more transient manner as whales move up and down the coast. Humpback whales in the western Atlantic (which are not currently listed) have increased in the New York Bight (Brown et al. 2018; Hayes et al. 2020; King et al. 2021; Zoidis et al. 2021), particularly during the feeding season, although it is unclear why whales are feeding here as opposed to the historical feeding grounds farther to the north (Katona & Beard 1990). The majority of humpbacks observed in the region are juveniles, and some have been observed for prolonged periods of time throughout a year and across years (suggesting the region is a primary feeding area for some individuals) while others are observed briefly and appear to use a broader range of areas (Brown et al. 2022). The focus of this study will be on fin and humpback whales for two primary reasons: 1) both species are commonly observed in New Jersey waters (Zoidis et al. 2021) and 2) these species are present year-round (although their presence varies by season and individual; Hayes et al. 2020). The tagging efforts in this study will provide movement data that will add to the limited knowledge base of both fin and humpback whales to improve our understanding of their behavior within the region and potential habitat overlap with wind lease areas and shipping lanes.

In recent years, whales (primarily juvenile humpbacks) have been observed with increasing frequency along near-shore areas off New Jersey and its surrounding states (Brown et al. 2018; Chou et al. 2022), which may be a result of increasing population size (NOAA 2019) or driven by shifting prey distributions and environmental conditions (Kraus et al. 2019). A better understanding of whale movement and habitat use is needed to assess the spatiotemporal overlap of whales with shipping lanes and other ocean user activities (e.g., fisheries, recreational vessels, etc.) to evaluate risks associated with vessel strikes (Laist et al 2001). Such information is incredibly important, particularly in light of the recent whale strandings along the coasts of New York and New Jersey. Cause of mortality cannot be determined for all stranded whales, however, a number of the recent cases indicated human interaction prior to stranding, i.e., either entanglement in fishing gear or of a ship strike (NOAA Fisheries). While there is no evidence that these whale mortalities are related to offshore wind activities (NOAA Fisheries), this study will provide baseline ecological data needed to evaluate habitat overlap with major shipping lanes and vessel traffic, as well as potential impacts of offshore wind development on whales in the region.

There are a variety of approaches that can be used to identify the presence, habitat use, and behavior of whales. These approaches included acoustic monitoring, surveys, and satellite tagging, each with their own strengths and weaknesses. Passive acoustic monitoring (PAM) via gliders or moored buoys is a cost-effective way to identify presence of species in an area based on their calls (e.g., Davis et al. 2020). However, calls can be detected over great distances (30+ km), depending on the species (based on the frequency and loudness of the call) and the amount of background noise in the area (Baumgartner et al. 2019, Davis et al. 2020). Thus, detections via PAM indicate that a whale is "in the area," but that area can be considerably large. Furthermore, acoustic detection does not provide information on the behavior of the detected whale in the area (i.e., foraging or transiting through the region). Finally, PAM is reliant on whales singing in the area, which does not always occur, and may be influenced by noise pollution (Tsujii et al. 2018). Aerial or ship-based surveys are other approaches that can provide species and location data for all whale species observed along a survey route. However, surveys provide a snapshot of what species are found at a particular place at a particular time, and do not provide information on the long-term behavior of the whales. Furthermore, it is difficult to get fine scale habitat use across time from surveys, as that would require near constant surveying of a region, which is often financially prohibitive.

Satellite telemetry is a commonly-used approach for estimating an aquatic animal's location in continuous space and yields time series of locations along an animal's path. Satellite tags have shown to be useful for obtaining a better understanding of baleen whale habitat use, behavior, and overlap with anthropogenic activities (Lagerquist et al. 2019; Aschettino et al. 2020). Although individual behaviors are not observed in tagged individuals, they can be inferred based on the types of movement the animal exhibits. For example, low speed and high turning angle movement in a specific area (called area restrictive search, or ARS) may suggest foraging behavior, while a more direct path may suggest traveling between habitats (Whoriskey et al. 2017). Thus, the satellite tagging of fin and humpback whales in southern New Jersey can provide information on the areas used, and the associated behaviors in these areas. In addition, the overlap of these areas with proposed wind farms and shipping lanes can be quantified to better understand the potential impacts of wind farms and boat traffic. Satellite tags are not permanent, but information they collect can be combined with environmental data to understand that factors that influence habitat selection (e.g., temperature, chlorophyll), which can allow for prediction of suitable habitat (Hazen et al. 2017).

This proposed study will provide valuable information on the ecology humpback and fin whales off southern NJ, offering a baseline with which to compare to during offshore wind construction and operation in the future. The proposed tagging study will also complement ongoing RMI research in the area. Slocum gliders have been and will continue to survey the region in the coming years, collecting oceanographic data, which can potentially be used to inform models predicting suitable habitat. The gliders are also equipped with PAM, so information gathered from satellite telemetry can potentially be analyzed with concurrent whale acoustic data.

4. Proposed Research

We are proposing a three-year project to tag humpback and fin whales in southern New Jersey (Figure 1). The proposed activities can be broadly grouped into three tasks described in detail below: 1) the tagging of whales, 2) the analysis of the data collected from the tags, and 3) the sharing of data and reporting results. Tagging activities will occur in the years 1 and 2 of the of the study, while the data analysis will occur primarily in years 2 and 3. Preliminary and final reports will be written as required by the NJDEP (Table 1).

Figure 1. BOEM wind lease areas (shaded areas) and the proposed tagging area in southern New Jersey (black box). This figure was obtained from the MARCO data portal (https://portal.midatlanticocean.org/) and modified to include the study area.

Table 1. Proposed timeline for different activities over the proposed three year project period.

4.1: Satellite tagging

Tagging will occur in the first two years of the project, with an anticipated deployment of approximately 20-25 tags per year, for a total of 40-45 tagged whales. We have budgeted for 45 tags in total, but tag failure or short duration of the tags might occur, resulting in fewer than 45 successful tagging events. Exactly when tagging occurs will depend in part on when funding for the proposal is secured. Construction of the wind farms has not yet begun, but is anticipated to occur during the proposed project period. A primary goal of the RMI is to assess the impacts of offshore wind on organisms in the area. Barring delays in construction, that means that our tagging activities will occur both prior to construction, and during construction, which may allow for comparisons of habitat use and behaviors between the different phases. If construction does not begin before tagging is completed, the observed habitats occupied and behaviors within them can be used as a baseline for future studies post-construction.

We anticipate approximately 54 trips (27 each year) will take place over the course of the project to account for initial training of the Rutgers boat captain, but also the possibility of unsuccessful trips. Project member Dr. Alex Zerbini is the tagging expert on the project (see Expertise section below), and he will be heavily involved in the training and tagging operations throughout the course of the project. Until all members of project are sufficiently trained in the tagging process, all trips must involve Dr. Zerbini. Because he lives in Seattle, WA, tagging operations will occur in one-to-two-week long intervals to maximize efficiency and reduce the number of trips to NJ. Our plan is to spread out tagging across the year as much as possible to better understand habitat use across seasons. However, weather conditions will likely limit our ability to tag whales from spring through fall. Initially, tagging will be clustered solely around trips with Dr. Zerbini present, but once the team is sufficiently trained to tag in his absence, tagging will be able to be spread out more temporally. The exact duration of each tagging period, and when they occur in the calendar year will depend on a number of factors, including the availability of all project personnel, boat access, the likelihood of whale encounters, weather conditions, and other logistics. Ideally, we plan for an even split of tags between humpbacks and fin whales, but encounter rates and tagging success may skew the number of tags more heavily towards one of the species. In addition, we plan to limit tagging of whales in the same location (i.e., those in a pod foraging together) when possible, to avoid the potential for duplicating tracks if the individuals remain together. However, tagging of multiple whales in a single location may occur if encounter rates are low for a given species.

There will be two focus areas for tagging deployment: 1) the planned Ocean Wind I and II and Atlantic Shores wind energy areas and 2) the vessel traffic lanes leading to the Delaware River Port Complex (these areas are in the box in Figure 1). Because these areas encompass a substantial amount of ocean, we will undertake an opportunistic vessel survey format to maximize the likelihood of species encounters. Project member Danielle Brown is heavily involved in the whale watching community in NJ and has developed a network of communication with vessels throughout the state. We will also consult with local fishermen and the RUCOOL team and others that are conducting PAM as part of the RMI. We will utilize as much information on recent whale sightings from this network as possible to aid in our selection of survey areas for each trip. In the absence of recent information on sightings in particular areas, we may utilize historical PAM detections or historical sightings (in the relevant seasons) to help determine suitable areas to search for whales. Tagging trips will occur during daylight, although the duration of each trip will vary based on weather conditions, tagging success, etc. All humpback and fin whales encountered will be photographed prior to tagging and given a unique identification number. Species other than humpback and fin whales that are encountered will also be documented and photographed for potential future use by the RMI team. Once a whale is tagged, we will notify the RUCOOL team of its location, and will periodically update them on the location of all tagged whales, so that they may maneuver their gliders, when possible, to these locations to collect oceanographic data and conduct PAM.

We propose the use of a combination of Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET, Andrews et al., 2008) and transdermal (Zerbini et al., 2017) satellite tags, both equipped with Argos satellite technology. The reason for multiple tag types is that there are tradeoffs associated with each type. LIMPET tags will be the primary tag used in the project, as they are less invasive and are suitable for smaller whales, but have a shorter duration compared to transdermal tags. Transdermal tags may be used if we encounter large whales, such as adult fin whales.

The LIMPET tag is small, lightweight, and is attached to the external surface of the body or the dorsal fin with typically two barbed darts. Darts are designed to penetrate the skin and typically anchor at the dorsal fin or dorsal ridge. Depths of penetration of LIMPET tags will vary depending on the species. LIMPET tags are typically smaller, lighter, and less invasive than integrated-implantable tags, which makes them ideal for use in younger animals. However, tag duration can also be lower. Duration of LIMPET tags vary by species, but the overall mean attachment duration is between 10-30 days. Younger humpback whales are common in the New York Bight (Stepanuk et al. 2020; Brown et al. 2022), thus only LIMPET tags will be deployed on these smaller animals, or on juvenile fin whales. LIMPET tags are deployed remotely using bolts fired from crossbows or pneumatic rifles, allowing movement data to be obtained without the need for physical capture and restraint, and with negligible physical impact or behavioral disturbance. The tag antenna will be inserted into the hollow shaft of a projectile bolt; and on contact with the whale this dart will fall away from the whale and be retrieved by a tether line, leaving only the transmitter attached to the whale.

In contrast, transdermal tags are are designed for proportionally longer deployment than most other tag types. These tags anchor below the fascia, a stiff connective tissue layer that underlies the blubber (Mate et al., 2007). Maximum durations vary by species and tag types, and typically range from several weeks up to several months in baleen whales, including humpback and fin whales two years (e.g., Mate et al., 2007; Zerbini et al., 2006; 2018; Sepulveda et al., 2018). Because larger whales are likely to have thicker blubber layers, adult fin and humpbacks may be targeted with this tag type. Intradermal tags will be remotely deployed either when animals approach a vessel or during directed approaches made the tagging vessel. Intradermal tags are usually attached using a modified pneumatic line or hand-held poles. The tag is held at the front of a plastic or aluminum carrier prior to deployment. The delivery devices slide into the barrel of the pneumatic rifles prior to firing. The tags disengage from the delivery devices upon contact with the whale and remain attached to the animal. The carrier falls on the water and is recovered for future use on another deployment. Satellite tag deployment will be conducted following best practices guidelines for cetacean tagging as described in Andrews et al., (2019).

Satellite transmitters are equipped with a Platform Transmission Terminal (PTT) from which uses the Argos system (www.argos.org). PTTs will transmit messages at a transmission frequency of 401.650 MHz (± 30 kHz) to polar orbiting ARGOS satellites flying at an altitude of 850km according to a pre-specified repetition rate (typically 30-45s for cetaceans). PTTs are numbered and the message sent to the satellite includes the PTT id. Satellites can receive messages from a platform during the time in which the platform is within visibility, or when the satellite is above the horizon. Argos messages are received by one or more satellite near simultaneously. These messages are stored on the onboard recorder and retransmitted to the ground each time the satellite passes over one of multiple receiving stations located in various continents. Messages are then transmitted to global processing centers located in the US and in France where messages are processed and location data are calculated. The following processing is carried out at the global processing centers: (a) verification of message quality, reception level, time-tagging, transmitter identification number, sensor message lengths and receiver frequency value (to compute the location); (b) message time-tagging in coordinated universal time (UTC), (c) Message classification by platform and by chronological order, and (d) Data processing. Processed information is then stored in a PPT-specific database and transmitted to the end user via the Argos portal (www.argos-system.org). The end user has a user-id and password to access the portal and download the data. Because we are using transmitters provided by a tag manufacturer, Wildlife Computers, the Argos data can also be stored in a database provided by the manufacturer, where processing of specific features of their tags (e.g., calculation of depth profiles) is performed to facilitate access to the data. One advantage of using the tag manufacturer portal is that data can be shared directly with collaborators of the project.

4.2: Data Analysis

The satellite tags provide a time series of location data for the duration of the tag. These data are then used construct a "track" of the tagged individual from the time it was tagged. Tracks can be used to estimate the spatial range of the whale over tagging period, and the percentage of time spent in the potential wind areas and in major shipping lanes can quantified. In addition, the types of behaviors in these areas can also be inferred from whale tracks to determine if the whales are actively foraging or just transiting through an area.

Inference of behavior based on movement through space can be highly correlated, meaning that the individual appears to moving on a direct path through the environment (often called transiting). In contrast, movement may be uncorrelated, or negatively correlated, which means that the individual is frequently changing directions in a localized area, also called area restrictive searching, or ARS (Figure 2). ARS movement is generally associated with foraging. Thus, classifying animal movements is based on quantifying how correlated, or uncorrelated the movement direction is for portions of the track. While this is conceptually straightforward, doing so is complicated by the fact that there is some imprecision in the exact location of the individual provided by the ARGOS satellite tag. In other words, the observed movement of a tagged individual may be in part an artifact of the precision of the reported location, or what is commonly referred to as observation error (Hoenner et al. 2012). Accuracy of the ARGOS tags improves as you move towards polar latitudes, and can vary between hundreds of meters to hundreds of kilometers. Note that particularly uncertain data points can be removed from the tracks, but processing of the data is still required to account for imprecision of the tags, and may be able to reduce uncertainty to within a few km (Jonsen et al. 2020). Accurate classification of behaviors therefore requires distinguishing between the actual track of the organism and the imprecision of the tag location. Behavioral switching state-space models are commonly used in the analysis of animal movement data, as they allow for the estimation of the underlying process (i.e., the actual movement directions and distances) while taking into account the impact that observation error may have on the observed tracks (e.g., Jonsen et al. 2005, 2013; Breed et al. 2017). State space models are computationally complex, and can be implemented in either a maximum likelihood or Bayesian framework (Silva et al. 2014; Breed et al. 2017). The exact formulation of the state-space model to be used has not been determined, and there are a number of packages that have been develop and tested for quality control in the R programming language, including the bsam (https://rdrr.io/cran/bsam/) and the foieGras packages (https://rdrr.io/cran/foieGras/). The hierarchical Bayesian basm package may become the preferred approach, as it allows for joint estimation of parameters, as well as individual effects, which is advantageous when you have some short duration tracks that cannot be modeled individually (Aschettino et al. 2020). Application of a state space model to the ARGOS tracks will allow us to determine to movement routes and foraging locations of tagged whale, and how they overlap with the proposed sites and with the shipping lanes to be used by vessels in the construction of the wind farms.

Information on whale locations, and time spent in each location, can allow for the calculation of the relative risk of a vessel strike or encountering a wind turbine (Guzman et al. 2012;

Rosenbaum et al. 2014; Garcia-Cegarra et al. 2019). The basic idea in these analyses is to combine information on the whales' locations with information on shipping traffic and turbine location, and quantify the amount of overlap between these potential threats. The amount of overlap in space can be considered a measure of the relative risk of a whale encountering a vessel in a given area. Different metrics can be used to quantify the relative risk in a given area. For example, Maxwell et al. (2013) calculated the cumulative utilization impact (CUI) for a range of marine organisms (including whales) in the eastern Pacific, that quantifies risk to a variety of anthropogenic activities, including vessel traffic. This metric was also used by Rosenbaum et al. (2014) for humpback whales off West Africa. The relative risk of impact can also be fine-tuned to account for different vessel types based on size or speed, as such factors may impact the lethality of a strike if one were to occur (Portal et al. (*in review;* DOI: https://doi.org/10.21203/rs.3.rs-2422434/v1).) It is important to note the amount of overlap between whales and a hazard (vessel or turbine) is not an absolute measure of risk (i.e., the probability a whale will be struck by a ship or collide with a turbine). This is in part due to the unknown overall density of whales in the area (since not all whales are tagged), but also due to the coarse spatial nature of the data. Presence of a whale or hazard is quantified over gridded spatial areas (e.g., 5 km x 5 km or 10 km x 10 km areas), such that both a whale may be in the same grid as a hazard but not encounter it. For vessels risk, we will initially focus on overlap with static shipping lanes. If time permits, we may expand the analyses to include AIS data from individual vessels (available from https://marinecadastre.gov/). Nevertheless, such analyses are incredibly useful for understanding how whale habitat overlaps with vessel traffic and other potential stressors, such as turbines.

Figure 2. Movement tracks of blue whales in the Norwest Atlantic showing ARS (red) and directed movement (transiting; black) Figure taken from Lesage et al. (2017).

Ecologists often view habitat characteristics to be relatively static in space and time, but that assumption is routinely violated in the marine environment. While water depth is constant in a given location, other factors that influence the productivity (e.g., nutrient supply, temperature) may change spatially from year to year. Suitable marine habitat for a given species is therefore dynamic, and species distributions may shift over time in response to changing conditions. Foraging habitats or migration routes for whales may shift annually as conditions vary, so it is imperative to identify environmental variables that may be useful predictors of whale occurrence in an area.

Tagging information is useful to understand where whales have been over some period, but it is generally not feasible to have whales continuously tagged over long periods of time. Development of habitat models that identify important variables associated with the presence of whales in an area is important as it allows for us to predict suitable habitats outside of the observed habitats occupied from tagged whales. A variety of approaches have been applied to model the habitat preferences of marine mammals (e.g., Freitas et al. 2008; Hazen et al. 2017; also see the special issue of Endangered Species Research at https://www.int-res.com/journals/esr/esr-specials/beyond-marine-mammal-habitat-modeling/). One such approach that we will explore was developed by Freitas et al. 2008, who used a mixed-effect Cox proportional hazard (CPH) model to infer habitat selection based on the concept of first-passage time (FPT). FPT is measure of how long an animal spends in a specified area, and can help identify environmental variables that best explain the time spent in different areas, taking into account the individual variability, and can measure how animals respond to environmental conditions, by calculating relative habitat preferences. Freitas et al. (et al. 2008) successfully applied their model separately to 12 tagged white whales and 18 tagged ringed seals (n=18).

We will also explore the approach outlined by Hazen et al. (2017), who developed habitat models for blue whales (based on 108 tagged whales) in the California Current. They explored two nonlinear approaches for quantifying habitat in relation to environmental variable; generalized additives mixed models (GAMMs), and boosted regression trees (BRTs). Each approach has different underlying assumptions, with boosted regression trees having fewer overall assumptions (Elith and Leathwick 2009). These approaches can predict the probability of occurrence in an area based on a range of environmental variables, and determine which variables have the greatest influence on presence in an area. Note that telemetry data represents only information on presence, but these approaches require information on both presence and absence to effectively identify variables driving occupancy in a given habitat. To account for absences, we will follow the approach of Phillips et at. (2009) whereby simulated whale tracks are created based on observed turning angles and movement distances (determined from the state-space analysis described above). These simulated tracks represent 'pseudo-absences,' and are an important piece to include to improve model accuracy (Hazen et al. 2017). The variables we will use in the habitat models will not be collected as part of this study. Instead, we will utilize data that are routinely collected and are available via NOAA's Coastwatch tool (https://coastwatch.noaa.gov/cwn/data-access-tools/coastwatch-data-portal.html). Possible variables to be explored in the habitat models include, but are not limited to: depth, sea surface temperature (mean and variability), sea surface height anomaly, and chlorophyll-a concentration. These variables have a somewhat coarse spatial resolution, so we will also explore using finer scale measurements of ocean variable measures by the Slocum gliders in the study area that overlap in space and time with individual tagged whales. The ability of a given model to match patterns in the observations is referred to as the model "fit." Adding more predictors and model parameters generally results in better model fits, but with the tradeoff of poor predictive power (called overfitting). Thus, selection of an appropriate model balances the fit to the data with the ability to make accurate predictions. Model selection will be determined using both Akaike's Information Criterion (AIC), and also using the area under the curve (AUC). AUC metrics are meant to maximize true positive in prediction while minimizing false positives, and are calculated using cross-validation, where a portion of the data set is used to fit the model (training data), and the remaining data are used to test the prediction accuracy of the model. It is possible for both GAMMs and BRTs to overfit the data, so cross-validation of the model via AUC metrics is an important step in the development of habitat models for this project.

The combination of tagging data and collection of PAM data in the study area has the potential to provide some useful insights into the effectiveness of PAM to monitor whales. We will communicate regularly with the glider team to provide the locations of tagged whales, so that, when possible, gliders may be moved into the vicinity of the whales to collect acoustic signals but also oceanographic data. PAM data can be combined with behavioral states to better understand if and how often whales communicate during ARS or transiting. However, it is important to stress that detection of a whale via PAM in the vicinity of a tagged whale does not mean that the tagged whale was the source of the sound. Absence of PAM detection within range of a tagged whale may help better understand the likelihood of a whale being detected via PAM.

The data analysis portion of this project will occur primarily in years 2 and 3 of this project (Table 1). In year 2, or possibly before, we will begin to develop the various models to analyze the tagging data, even though all of whale tracks will not have been collected. We will develop a flexible analysis framework that will be rerun periodically as new data are collected.

Task 4.3: Data Sharing and Reporting

Identification photographs of humpback and fin whales will be shared and compared with local and regional whale catalogs (used in Brown et al. 2022) to obtain sighting histories of the individuals observed and tagged. Species sightings will be uploaded in real-time to the Whale Alert application for easy access by managers and mariners.

Within a year of completion of the study period, satellite tag data will be uploaded to the Animal Telemetry Network Data Portal (https://portal.atn.ioos.us/) to facilitate regional data sharing. The reason for the delay in sharing the data is to allow for sufficient time to publish results from this study in peer-reviewed articles. In addition, within a year of project completion all data and code will be made publicly available in the Github site of Dr. Wiedenmann (https://github.com/John-Wiedenmann).

The research team will regularly provide the RMI with summary updates of the species encountered and tagged. On an annual basis, we will submit a report to the RMI including a summary of the fieldwork conducted in that year, the whales that were tagged, and the status of data analysis. More frequent reports will be provided if requested. Additionally, at the completion of the contract period a final report will be submitted to the RMI that includes a summary of all tagging expeditions, data analysis, and data sharing.

1.4 Expected Outcomes and Evaluating Success

The overall objective of this proposal is to fill this knowledge gap through the use of satellite tagging of fin and humpback whales to better understand their habitat use and behavior in the region. To achieve this overall project objective, there are four specific objectives that we will continually assess to determine if they are being met. These specific objectives are to 1) tag the whales, 2) process the track data with the state-space behavioral models, 3) quantify overlap of the tracks with proposed lease areas and shipping lanes, and 4) develop habitat model to help predict whale presence in areas in the absence of tagged whales.

We expect to tag approximately 40-45 whales throughout this project. These tags are to be spread out over the course of the project, with an expected even split in Years 1 and 2. Additional tagging may occur in Year 3 if we have not met out goal number of tagged individuals, or if surplus funds are available. We will continually assess the success rate of our trips to identify factors that may improve the likelihood of successfully tagging whales. We will also evaluate how our successful tagging events are distributed across space and time to ensure that whales are not all tagged in the same season within a year or from the same area.

Concurrent with our tagging efforts, we will begin to develop the state-space behavioral models immediately using data provided by project co-PI Dr. Zerbini from tagged whales from previous tagging studies. Early development of the models will allow for anticipation of possible issues once we begin to process track data collected from this project. We will then begin to process track data as it becomes available, and success will be measured in the ability for the models to converge and identify distinct behaviors. As described in section 4.2, different model packages have been developed to process satellite track data, so if one such model is not successful, we can explore alternative models. The expected outcome for this section of the smoothed animal tracks, with uncertainty, and estimated behavioral states, which will be used quantify overlap with wind areas and shipping, and also in the habitat model.

The movement tracks and behavioral states will then be used for objectives 3 and 4. We will first quantify overlap within wind areas and major shipping lanes, where the expected outcome here is measures of the residence time of whales (at the individual level and across all whales tagged) within the different areas, by species and season. We may also explore ship strike risk using AIS track data of individual ships, in which case we can also compute a relative risk of ship strike with different vessel types in the areas. Our tagging efforts may occur both in the pre-construction and construction phases in some of the lease areas. If that occurs, our analysis for objective 3 will account for these distinct periods to look for differences in habitat use that might result from the construction activities.

Development of the habitat models will begin once we have a sufficient number of individual tracks, likely by the end of our first year of tagging. Multiple models may be explored, and early development will help ensure identification of issues that might arise. Success for this objective will be the identification of environmental factors that help predict the likelihood of whales being in a particular area. If successful, the model can be used to predict whale presence in areas outside of those where whales were observed from their track locations, based on the environmental variables in those regions. Results from the habitat modelling may change as more data are added to the model, so the success of the habitat modelling approaches can only be determined once all data have been collected and the final model is run.

In addition to these outcomes, we expect to have at least two peer-reviewed publications from this work. One paper will focus on the animal tracks and overlap with wind areas and shipping lanes. Depending on the amount of information, however, this paper could be split into two with one focusing on just the wind areas, and one focusing on vessel risk. An additional paper will focus on the habitat model. Other publications are also possible from this work. For example, we have agreed to collaborate with Dr. Danielle Cholewiak (from NOAA's Northeast Fisheries Science Center) who is tagging fin whales in New England, and combine our data to get a broader understanding of their behavior and movements in the region. Additional publications might also result if we are successful in overlapping gliders with tagged whales in the study areas, or with overlap between tagged whales and the PAM network.

A final outcome from this work will be to post the satellite tag data to the Animal Telemetry Network Data Portal (https://portal.atn.ioos.us/) to facilitate regional data sharing.

4.5 Public Outreach and Education

Whales in New Jersey have generated a substantial amount of interest in recent years, and whale watching has become a popular recreational activity. Social media facilitates the widespread sharing of whale sightings from both whale watching and the general public, which means that whales in New Jersey already have high visibility. Due to the resident nature of some humpback whales in the New York Bight (Brown et al. 2019), it is highly likely that tagged whales will be observed and photographed by the public. Therefore, it is important that the public understands and supports this initiative. We are proposing several objectives to engage the public through education and outreach. The first is to establish a social media page dedicated specifically to this project. This page will provide project info and updates to the public, along with sightings information. Similar social media pages have been successful for other whale telemetry projects along the US East Coast (e.g., Mid-Atlantic Whale Monitoring Project). Another objective is to make whale position data available to the public. Individual track images can be shared via social media posts, and as stated previously, we will all post satellite data to an online portal within one year of completion of the project. Lastly, as Director of Research for Gotham Whale, Danielle Brown maintains strong relationships with whale watching companies in New Jersey. We plan to hold virtual info sessions to encourage and assist these companies in educating their passengers on the project details and the importance of this work.

5. Budget and Budget Justification

An annual breakdown of funds is provided in the Table below, separated out personnel costs (salary and fringe), project supplies, travel for Rutgers personnel, and the subaward for Dr. Zerbini at the University of Washington, which includes both salary and travel costs for him. A more detailed breakdown of each category is provided below.

Category	Year 1	Year 2	Year 3	Total
Personnel (salary and fringe)	[redacted]	[redacted]	[redacted]	[redacted]
Supplies	[redacted]	[redacted]		[redacted]

Travel	[redacted]	[redacted]	-	[redacted]
Tuition	[redacted]	-	-	[redacted]
Equipment rental (boat)	[redacted]	[redacted]		[redacted]
Subaward (direct and indirect)	[redacted]	[redacted]	[redacted]	[redacted]
Direct costs	[redacted]	[redacted]	[redacted]	[redacted]
Indirect costs (10%)	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	$929,437

Personnel

A total of [redacted] is requested to cover salary ([redacted]) and fringe ([redacted]) over the three-year project. The amount in Year 1 is to support a 12-month graduate assistance-ship (GA; with a [redacted]% fringe rate), and in Years 2 and 3 to support a postdoctoral researcher (with a [redacted]% fringe rate each year; see Table below). Note that the salary for the graduate assistant and postdoc are for project member Danielle Brown, who is finishing her Ph.D. and will transition to a postdoc during the course of this project. One half month of summer salary is requested for PI Wiedenmann ([redacted] per year with [redacted] in fringe at [redacted]%). In addition, an hourly assistant is budgeted in Years 1 and 2 to assist with the field work component of the project.

	Year 1 (GA)	Year 2 (Postdoc)	Year 3 (Postdoc)
GA Salary	[redacted]	-	-
GA Fringe (32.63%)	[redacted]	-	-
Postdoc Salary	-	[redacted]	[redacted]
Postdoc Fringe (71.60%)	-	[redacted]	[redacted]
Summer salary	[redacted]	[redacted]	[redacted]
Summer salary fringe (7.65%)	[redacted]	[redacted]	[redacted]
Hourly Assistant Salary	[redacted]	[redacted]	-
Hourly Assistant Fringe (7.65%)	[redacted]	[redacted]	-
Total	[redacted]	[redacted]	[redacted]

Supplies

A total of [redacted] is requested for project supplies, with [redacted] in Year 1 and [redacted] in Year 2. The bulk of the supplies costs result from the purchasing of LIMPET and transdermal satellite tags and the additional equipment needed to prepare and deploy the tags. A breakdown of the costs is provided in the table below. Note that we currently have permits to use LIMPET tags only, and are applying for transdermal tags for use in fin whales. Therefore, transdermal tags would be purchased in Year 2. If for some reason use of transdermal tags is not approved, we will apply the amount allocated for transdermal tags to purchase additional LIMPET tags.

Item	n	Year 1	n	Year 2
Limpet tag ([redacted] per tag)	20	[redacted]	15	[redacted]
Transdermal tag ([redacted] per tag)	0	-	10	[redacted]
Tag sterilization		[redacted]		[redacted]
Limpet deployment bolts ([redacted])	6	[redacted]		
Dan inject gun plus accessories	1	[redacted]		
Transdermal deployment gun plus accessories	1	[redacted]		
Transdermal deployment carriers ([redacted] each)	3	[redacted]		
Practice supplies				
Dummy Limpet tag (includes bolts; [redacted])	1	[redacted]		
Dummy transdermal tag	1	[redacted]		
Target practice supplies		[redacted]		
Misc supplies needed for preparation and deployment		[redacted]		
Water proof marine field gear ([redacted] per set)	3	[redacted]		
Laptop	1	[redacted]		
Argos Satellite time ([redacted] per month per tag)	30	[redacted]	60	[redacted]
Total		[redacted]		[redacted]

Travel

A total of [redacted] is requested for travel of Rutgers personnel involved with the project, with [redacted] in Year 1 and [redacted] in Year 2. The annual costs assume 40 trips per year (across personnel) from main campus to the Rutgers University Marine Field Station (RUMFS) in Tuckerton, NJ. The breakdown per year is an estimated 7,600 miles driven ([redacted] per year), and [redacted] in lodging costs per year at the RUMFS dorm for nights when personnel need to stay over (25 nights total per year at [redacted] / night).

Tuition
A total of [redacted] is requested for tuition and associated fees in Year 1, approximating 4 total credit hours.

Equipment Rental
A total of [redacted] is requested to rent vessels to conduct the tagging, with [redacted] in Year 1 and [redacted] in Year 2. These costs are based on an anticipated 27 trips per year, with a cost per trip of [redacted]. The cost per trip is based on the RV Rutgers, which has a base cost of [redacted] per 8-hour day. Trips of longer duration, or that use more fuel will cost more than the base amount. Because we will be travelling offshore in search or whale, we anticipate that individual trips will exceed the base rate, and approximate a per trip cost of [redacted].

Subaward
This work will be done in collaboration with scientists at the University of Washington (UW). A total of [redacted] is requested for a subaward to the UW. This award includes salary (1.5 months per year plus fringe [redacted]%) in Years 1, 2, and 3 (total = [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3 = [redacted] across three years). In addition, [redacted] is included for travel for UW personnel, with [redacted] per year in Years 1 and 2. Travel costs include 3 flights per year ([redacted] per year), and 25 days total per year of travel, with hotel costs ([redacted] per year), per-diem ([redacted] per year), and rental car ([redacted] per year). Total annual direct costs of the subaward are [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3. The off-campus indirect rate is [redacted]%, so indirect costs are [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3.

Direct Costs
Total direct costs for the project are [redacted], with [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3.

Indirect Costs
There is a 10% indirect rate cap for these funds. Total indirect costs for this project are [redacted], with [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3.

Total Costs
The total estimated project cost is $929,437, with [redacted] in Year 1, [redacted] in Year 2, and [redacted] in Year 3.

6. Expertise

The project team consists of Dr. John Wiedenmann (Rutgers University), Danielle Brown (Rutgers University), and Dr. Alex Zerbini (University of Washington).

John Wiedenmann, Ph.D.

Dr. John Wiedenmann is an Assistant Professor in the Department of Ecology, Evolution, and Natural Resources at Rutgers University. His research focuses on applied questions related to the management and conservation of marine species. In particular, Dr. Wiedenmann utilizes a range of quantitative approaches to identify robust assessment and management policies to support the sustainable management of global marine fisheries, and the recovery of depleted marine fish and mammal populations. Example focal research species include Antarctic krill and blue whales in the Southern Ocean, summer flounder, black sea bass, golden tilefish, scup, butterfish and humpback whales in the Mid-Atlantic, and Atlantic cod, haddock, and other groundfish species in New England.

Danielle Brown, M.S.

Danielle Brown is currently pursuing a Ph.D. at Rutgers University under the mentorship of Dr. John Wiedenmann. Her dissertation research focuses on using specimens of opportunity from stranded humpback whales to investigate their long-term foraging ecology and stress patterns. Danielle also works as the Director of Research for Gotham Whale, a non-profit research and education organization that collects and manages sightings data on whales in the New York Bight. Danielle's work with Gotham Whale has primarily centered on the increase in humpback whales over the last 12 years, including their residency patterns, population characteristics, and overlap with vessels.

Alex Zerbini, Ph.D.

Dr. Zerbini's research is focused on marine mammal population biology, assessment and management. He has been developing studies to assess abundance and distribution, movements, migratory routes, migratory destinations and habitat use using survey and telemetry methods. This work includes design and implementation of aerial and vessel surveys for data collection and deployment of telemetry instruments. He also uses quantitative techniques to compute cetacean abundance and trends, to assess population status through population dynamics modeling, and to develop movement and habitat models. Dr. Zerbini is a worldwide leading expert on the development and application of satellite telemetry technology for large cetaceans. This work has been highly collaborative, has involved a broad team of experts in cetacean biology, engineering and tag manufacturing, and has led to development of robust and safe methods to track whales at sea.

Dr. Wiedenmann is the project lead and will be responsible for the overall running of the project. Dr. Zerbini is the expert in tagging and will train Ms. Brown and Dr. Wiedenmann in the tagging of whales, and be involved in the majority of tagging trips. Until they are sufficiently trained, all trips will involve Dr. Zerbini, but he will continue to assist in tagging after successful training. Ms. Brown will be responsible for running most of the field-based activities, including scheduling of, and participation in the trips, tag preparation, etc. She will also will be the lead analyst in the modeling activities, under the supervision of Dr. Wiedenmann, and with the guidance of Dr. Zerbini. Ms. Brown will also take the lead on public outreach and education. Dr Wiedenmann will be responsible for all reporting on progress of the project.

7. Resources

The team is well-equipped to conduct this research. Rutgers has a fleet of vessels that can be chartered for a variety of projects (https://marine.rutgers.edu/about-us/facilities/; https://rumfs.marine.rutgers.edu/about-us/rumfs-facilities/small-vessels/). Rutgers also has a marine field station situated on Great Bay, in Tuckerton, NJ, which is within the proposed study area (Figure 1). The field station will be used as the launching point for all trips for this project.

Tagging marine mammals requires permits from the NOAA. We are in the process of applying for our own permits for this project, but we also have the capability of working under existing permits. Dr. Zerbini is currently permitted to tag humpbacks in our region, and we have agreed to collaborate with Dr. Danielle Cholewiak (from NOAA's Northeast Fisheries Science Center) on this project. She is currently leading a tagging study for fin whales, and is expected to have tagging permits by June of this year that we can work under (see attached letter of support). Our collaboration will entail combining data on fin whale movements across study regions to get a broader view of fin whale behaviors off the Northeast U.S.

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