Baseline Monitoring of Large Whales in the New York Bight

New York
Natural Heritage
Program

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Matthew D. Schlesinger

New York Natural Heritage Program

www.nynhp.org

A Partnership between the State University of New York College of Environmental Science and Forestry and New York State Department of Environmental Conservation

Lisa A. Bonacci

New York State Department of Environmental Conservation

www.dec.ny.gov

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Cover photos:

Top—Humpback named "Leukos" in the Great South Channel (Artie Kopelman, CRESLI)

Middle—NOAA Ship Gordon Gunter (Jennifer Gatzke, NEFSC/NOAA; https://nefsc.wordpress.com/category/right-whale-survey/); Humpback tail fluke (© 2014 Artie Raslich, courtesy of Gotham Whale); Twin Otter airplane (NEFSC/NOAA; http://www.nefsc.noaa.gov/psb/surveys/aerialsurveys.htm)

Bottom—bottom-mounted recorders (Protected Species Branch, NEFSC/NOAA); fin whales off of Montauk (Artie Kopelman, CRESLI); lunge-feeding humpback (Philip Ng, courtesy Gotham Whale); ocean gliber (Mark Baumgartner, WHOI);sperm whale mother and calf (Gabriel Barathieu, creative commons license by SA 2.0)

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External reviewers:
Dr. Artie Kopelman, Coastal Research and Education Society of Long Island
Nicole Mihnovets, Columbia University
Dr. Aaron Rice, Cornell University, Bioacoustics Research Program
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Ali Chase & Michael Jasny, Natural Resources Defense Council
Mina Innes, New York State Department of State
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Introduction

Cetaceans, including large whales, can be found year-round in the waters of the mid-Atlantic, including the New York Bight. This area also falls within critical migratory pathways for certain species. Some information on the distribution, abundance, and behavior of large whales in the New York Bight is available from surveys (Sadove and Cardinale 1993, Cornell Lab of Ornithology 2010, DiGiovanni Jr. and DePerte 2013, NEFSC and SEFSC 2013), whale-watching trips, and stranding records. However, experts agree that available information on the occurrence and distribution of large whales in the Bight is inadequate for management and conservation planning. This lack of information, coupled with growing concerns over ship strikes and entanglements, as well as planning for proposed offshore wind energy and other human activities, made long-term monitoring of large whales in the New York Bight a priority for the New York Department of Environmental Conservation (NYS DEC). Planning for a monitoring program accelerated in 2013 when the NYS DEC entered into a Memorandum of Understanding with the New York Natural Heritage Program (NYNHP) to work together on a report of options for baseline monitoring of whales in the Bight. The survey plan outlined in this report will provide a basis for a long-term monitoring program.

NYNHP was tasked with working with NYS DEC staff to determine the most appropriate survey methods to meet the state's information needs by considering published and gray literature and expert opinion to construct a scientifically defensible baseline survey. For the purposes of this planning, the New York Bight was defined as the area of ocean from the south shore of Long Island to the continental shelf break, matching the New York State Department of State's "Offshore Planning Area" (Figure 1). Given limited resources, effort would focus on six species of large whales: fin, North Atlantic right, humpback, sei, sperm, and blue whales. These species were chosen because they are listed as Endangered at both the federal and state level and are designated as Species of Greatest Conservation Need (SGCN) in the State Wildlife Action Plan (NYSDEC 2005). Data on other species would be collected opportunistically and targeted effort on additional species of interest would be considered in the future if funds became available. Finally, we decided early on in the process that inviting experts and other interested parties to a workshop to discuss survey methods would be an important initial step in planning.

On January 16, 2014, we convened such a workshop to discuss options for monitoring whales in the New York Bight at the NYS DEC Bureau of Marine Resources headquarters in East Setauket, NY. We invited experts and stakeholders from academia, NGOs, and federal and state governments. Interest in the workshop was high, with 41 people attending. After some introductory remarks, nine technical presentations were given, covering specific methodologies (aerial surveys, tagging, passive acoustics) and combinations of methods employed elsewhere (New Jersey, Massachusetts, the western Atlantic, West Africa). Several presenters offered their thoughts on the advantages and disadvantages of the various techniques and some suggested combinations they thought most appropriate for the NY Bight. Following the final presentation we had two hours of discussion on the pros and cons of different survey methods and refinement of survey objectives. The workshop agenda, attendee list, presentations, and meeting notes are in Appendix A.

In this report, we build on the workshop results and subsequent discussion as well as information from the literature to provide a number of options at different price points for baseline monitoring of these six species of large whales. In addition to broad-scale baseline monitoring of the full spatial extent of the Bight, baseline monitoring of the area in and around the shipping lanes is discussed. Growing concern about ship strikes emerged during internal discussions and discussions with NOAA subsequent to the convening of the workshop. It became apparent that we should not wait to gather the data we needed in order to address this issue. In designing the monitoring program we have attempted to integrate these two monitoring pieces in something of a nested design where both broad-scale monitoring and targeted monitoring are coordinated and complement each other.

We start by defining the survey's objectives, after which we provide some background on aspects of the biology of the whales that are the target of this monitoring effort. Next, we review individual techniques for monitoring whales. Finally, we present several options for combinations of methods to meet New York's information needs and provide additional detail on certain recommended options. We do not discuss costs (estimates were provided to senior managers at NYS DEC for budgeting purposes), funding options, or the timeline of survey work (more internal discussion on the mechanism for moving the work forward is necessary before this can be determined).

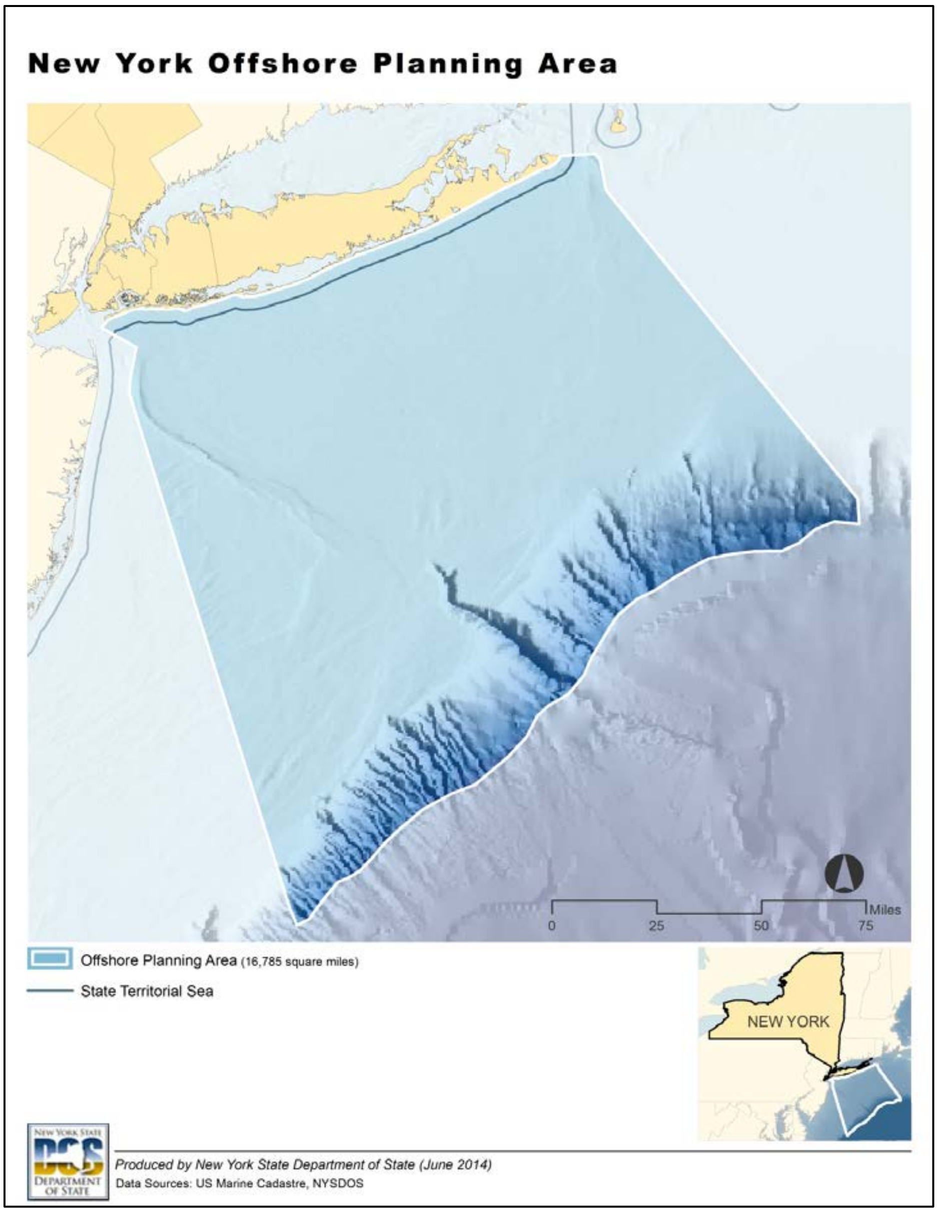

Figure 1. The New York State Department of State's offshore planning area, the study area for this project. Courtesy of NYS DOS.

Survey objectives

Information needs for New York's large whales are great, but management agencies such as NYS DEC must focus on the most critical needs, which we have identified as a baseline survey. We recognize that ocean ecosystems are changing so rapidly that the concept of a baseline is now somewhat quaint, but here we use the term "baseline" to indicate the generation of a snapshot in time against which future observations may be compared. In this way, our baseline survey relates to the similar concept of "status and trend" or "surveillance" monitoring.

Our thinking about the appropriate objectives for a baseline survey has evolved since this project started and has been influenced by the expert workshop, follow-up conversations with outside experts, reviews of the draft report, internal conversations and priority setting, and recent recognition of the immediate need for data to address the most imminent threats to whales.

While large whales face many threats, including entanglement in fishing gear, climate change, contaminants, offshore energy development, and anthropogenic noise (a thorough discussion of the threats to whales can be found in the species assessments for the State Wildlife Action Plan revision [NYS DEC in preparation]), the spatial distribution of many of these threats has not been identified and our focus is baseline monitoring rather than understanding particular threats and their consequences. However, ship strikes are a well known, visible, and possibly increasing threat with a defined spatial distribution. The expansion of the Panama Canal may exacerbate this threat. Therefore, we felt it was important that we begin now to gather information about whale occurrence in established shipping lanes in addition to beginning broad-scale monitoring of the entire Bight.

NYS DEC is defining its **immediate, or primary, monitoring objective** as follows:

- To determine the distribution, relative abundance, seasonality of occurrence, and interannual variability of those parameters for fin, humpback, right, blue, sei, and sperm whales at two spatial scales:
  - The entire New York portion of the Bight;
  - Within and around established shipping lanes

NYS DEC is defining its **longer-term, or secondary, monitoring objectives** as including, but not being limited to, the following:

- To determine behavior and residence time of individual whales in NY waters;
- To determine areas of conservation importance for state planning and for making recommendations to federal partners;
- To focus on additional areas of concern such as leased wind energy areas (with partners such as the NYS Energy Research and Development Authority and federal Bureau of Ocean Energy Management);
- To determine causes of whale mortality and their population impacts;
- To expand beyond the six large whales to include other species, such as northern minke whales (*Balaenoptera acutorostrata*), harbor porpoise (*Phocoena phocoena*), sea turtles, and others; and
- To collect behavioral, real-time and other data in and around the shipping lanes as warranted by the results of the baseline survey.

Some data toward these objectives may be obtained during the course of baseline monitoring (e.g., additional species may be sighted opportunistically, areas of conservation importance may be obvious after baseline monitoring), and some of these objectives may be pursued in addition to baseline monitoring if funding and staffing permit, but these objectives are not the focus of this report. Thus, the remainder of this report focuses on methodologies suitable for addressing the immediate or primary goals of collection of baseline data.

New York's whales

De Kay (1842) recognized four species of great whales as part of the New York fauna: "The Right Whale (*Balaena mysticetus*)," "The Sperm Whale (*Physeter macrocephalus*)," "The Beaked Rorqual (*Rorqualus rostratus*)," and "The Northern Rorqual (*Rorqualus borealis*)," with *Rorqualis australis* noted as extra-limital. We now classify these species as the North Atlantic right whale (*Eubalaena glacialis*), sperm whale (*Physeter macrocephalus*), minke whale (*Balaenoptera acutorostrata*), sei whale (*Balaenoptera borealis*), and humpback whale (*Megaptera novaeangliae*), respectively. By the time of Connor (1971), the known great whales of New York waters included the above species plus blue whale (*Balaenoptera musculus*) and fin whale (*Balaenoptera physalus*), with humpback being recognized as belonging to the state's fauna. Only scattered and isolated surveys have been conducted since.

Six species (all of the above except for the minke whale) are listed as Endangered by the federal government and the state of New York and are designated as SGCN in the state's Comprehensive Wildlife Conservation Strategy (CWCS) (NYS DEC 2005). While they have some things in common ecologically, they have many important differences that make employing a single survey methodology challenging to meet information needs for all the species. Below we extract information relevant to monitoring options about the known distribution, abundance, and natural history from the species accounts recently prepared for the revised CWCS, now called the New York State Wildlife Action Plan (NYS DEC in preparation) for each of the six species.

The fin whale is the most abundant baleen whale in the New York Bight and is found year-round there (Sadove and Cardinale 1993, Cornell Lab of Ornithology 2010, Morano et al. 2012, DiGiovanni Jr. and DePerte 2013) although individual fin whales are not necessarily resident year round. Sadove and Cardinale (1993) reported fin whales concentrating in later winter, spring, and summer near the shore, and in fall and early winter near the continental slope, based on surveys from the 1970s to early 1990s. They estimated that up to 400 fin whales may occur in the New York Bight at any one time. Fin whales were detected every day during Cornell Lab of Ornithology's (2010) 2008-2009 passive acoustic study, with a distribution of detections more or less matching that reported from the 1970s through early 1990s. Fin whales are the species most frequently struck by ships worldwide (Laist et al. 2001), and one was struck in April 2014 in New York Harbor.

Little is known about the sei whale, a close cousin of the fin whale, both in the New York Bight and throughout its range (Prieto et al. 2012). Whether this species occurs in the Bight year-round is unknown; the Bight may be part of its migration route. Sadove and Cardinale (1993) report detecting sei whales frequently in summer in the early 1980s but less frequently into the early 1990s. Recent years have yielded few sei whale sightings, but in May 2014 a sei whale was the victim of a ship strike in the New York Harbor.

The blue whale has always been rarely observed in NY waters, having been detected less than once a year on average from the 1970s to early 1990s as part of large feeding groups of fin whales (Sadove and Cardinale 1993). Cornell Lab of Ornithology's (2010) 2008-2009 passive acoustic study detected blue whales with somewhat greater frequency, on about 10% of sampling days. In both studies blue whales were detected in deeper water and far offshore.

Humpback whales were detected regularly in the 1970s through early 1990s (Sadove and Cardinale 1993), mostly off of the east end of Long Island, with considerable annual variation in the numbers of animals observed. Humpbacks were seen primarily in summer and early winter. Humpbacks were surveyed opportunistically by the Cornell Lab of Ornithology (2010) and detected on about one-third of sampling days from fall 2008 through spring 2009, mainly in spring and winter. Humpbacks have also been regularly observed opportunistically on scientifically based whale watches near New York City and out of Montauk (e.g., gothamwhale.com, cresli.org).

The North Atlantic right whale is among the rarest globally of the great whales and appears to use the New York Bight as a migratory corridor between winter calving grounds to the south and summer feeding grounds to the north. However, historically, they were caught regularly off Long island in the late winter and spring in the late 1600s and early 1700s by shore whalers (Reeves and Mitchell 1986). This species is infrequently but regularly detected in the Bight, with at least one sighting each year from the 1970s to early 1990s (Sadove and Cardinale 1993) and presence confirmed on about 20% of days during the Cornell Lab of Ornithology's (2010) passive acoustic study. More than any other great whales, right whales hug the coastline, putting them at increased risk of interaction with ship traffic (Kraus et al. 2005, Firestone et al. 2008). Additionally, recent studies in nearby areas off of New Jersey observed right whales year round, including mother calf pairs that appeared to be feeding (Whitt et al. 2013). Studies have found that this behavior puts them at greater risk of being hit by vessels (Parks et al. 2012).

Sperm whales have also been considered rare in New York waters but surveys have rarely targeted sperm whales specifically. Experts at the workshop believed they are far more common than thought previously. They are generally thought to occupy deeper waters near the continental slope, but were also documented in shallower waters off of Montauk Point (Sadove and Cardinale 1993, Scott and Sadove 1997) from 1983 to 1989. NOAA Fisheries (e.g., NEFSC and SEFSC 2013) has documented sperm whales consistently near the continental slope.

These differences among species in rarity, distribution, and habitat use make clear that present knowledge of the distribution of each species is incomplete, and that adequate monitoring of the deep-water species presents special challenges. Table 1 presents a summary with implications for monitoring. While different methods or combinations of methods can be expected to yield good information on fin, humpback, and right whales, gathering detailed information on sei, sperm and blue whales may be more challenging due to their primarily offshore distribution.

Whale monitoring techniques

Today's scientists interested in whale monitoring have many more options for characterizing whale distributions, abundance, and behavior than they did just two decades ago. Technological advances and accompanying analytical techniques have greatly expanded the toolbox from which whale researchers may choose their tools. The appropriate techniques for any given study vary by management objective, research questions, target species, spatial/temporal scales, resources available, and auxiliary data generated (Rosenbaum and Camhi, Appendix A). Methods vary in their ability to provide accurate species identifications, their precision in spatially locating animals, and their usefulness in generating estimates of abundance. And it follows that the outcomes from the varying techniques also differ in form and may include simple occupancy at a coarse scale, fine-scale distribution, abundance estimates, behavioral information, residence time, and habitat use.

A common element in all methods noted below is the need to account for imperfect detection of study target species. Recognition in the 1970s that not all animals present are detected, due to such factors as cryptic behavior, methodological limitations, weather conditions, and observer skill, led to the development of sampling methodologies and associated analytical techniques designed primarily around the need to account for imperfect detection rates. Marine mammal researchers were on the forefront of these important developments with their contributions to the line transect methodology of distance sampling (Buckland et al. 2001) for visual methods (and as adapted for passive acoustics; Mellinger et al. 2007). While the analysis of data from whale monitoring is not the focus of this report, we are intentionally considering only techniques that have analytical methods that can account for imperfect detection. As Taylor et al. (2014) state, a method's goal must be to maximize detectability and then account for uncertainty and error.

Table 1. Facets of distribution, rarity, and natural history of six whale Species of Greatest Conservation Need in New York that have implications for monitoring.

Species	Known NY Bight distribution	Relative rarity in Bight* and seasonal occurrence	Behavior and ecology	Implications for monitoring
Fin	Throughout	Most common; year-round presence	Known to be present year round, may be found in groups in NY Bight	May be able to get information more easily than for other species due to relative abundance and extensive distribution; occurrence in groups might also increase detectability
Sei	Unknown; erratic	Rare; unknown seasonal occurrence	Usually travel alone or in small groups	Challenging to get more than coarse / basic distribution information; data can be collected via passive acoustics but range of variability in calls is not well known
Humpback	Appear to be becoming more common along the coast; may be found in inlets	Common; mainly spring, summer, early winter	May be found in groups, abundance in area may vary from year to year	Easily detected via passive, but no robust automated detection algorithm to date, which means additional time is needed for analysis; aerial surveys may be best for monitoring animals using inlets
North Atlantic Right	Primarily coastal	Uncommon but regularly seen; late winter, spring, fall	Spend a lot of time at the surface relative to other species, but still a majority of time underwater; distribution may be changing	Detectability depends in part on behavior, which is still uncertain for the mid-Atlantic; acoustic methods may be best, with visual methods supplementary
Blue	Not well known, but primarily deep water	Rare; unknown seasonal occurrence		Challenging to get more than coarse basic distribution information; have been occasionally seen during visual surveys and detected acoustically
Sperm	Continental shelf, but also around Montauk point	Common; unknown seasonal occurrence	Deep diver and frequent vocalizer	Visual surveys alone may not yield adequate information; readily detectable via acoustics,

* A qualitative assessment of rarity relative to other large whales in the New York Bight based on existing data and expert opinion.

Visual methods

Visual methods (i.e., aerial and shipboard surveys) have been the industry standard for decades, and have an advantage over acoustic methods in having a long history of protocol development and prior data collection for comparison. The two primary visual methods are aerial surveys and shipboard surveys, which are often used in combination. We will discuss the two methods individually, and then compare them and present options for combining methods. We also briefly discuss opportunistic observations and citizen science.

Two primary transect designs are commonly employed: parallel lines and a zig-zag (also called "saw-tooth") design (Buckland et al. 2001). The most appropriate design depends on the shape and size of the study area, the cost of traveling between tracklines (in a saw-tooth design there is no wasted time traveling between tracklines), and the need for independence of tracklines (if properly spaced, parallel tracklines may be considered independent). Overlapping randomly generated saw-tooth designs, called "double saw-tooth" in New Jersey's recent study (Geo-Marine, Inc. 2010, Whitt et al. 2013), are another variation.

Aerial surveys

Aerial surveys are a primary component of many ongoing whale monitoring programs, like those of the New England Aquarium south of Cape Cod (Kraus et al. 2013), the Atlantic Marine Assessment Program for Protected Species, or AMAPPS (NEFSC and SEFSC 2013) and in the Mid-Atlantic for wind energy use areas of Maryland (http://www.briloon.org/research/research-centers/center-for-ecology-and-conservation-research/mabs/md). Aerial surveys as practiced by various researchers differ in equipment used, transect design, flight altitude, speed, number of observers, and methods for addressing detection biases (Table 2). Typically an observer sits on each side of the plane, there is often a separate data recorder, and to ensure animals on the trackline are detected there may be an additional observer facing down through a belly window or a belly camera as in Taylor et al. (2014).

Small planes, like the DeHavilland Twin Otter, Cessna 172, and Cessna Skymaster 337 are the standard platforms for aerial surveys. These planes are high-winged and highly maneuverable, are able to fly slowly (e.g., http://www.aoc.noaa.gov/aircraft_otter.htm), and when bubble windows and/or a belly window are installed they allow observers to detect animals as close to the trackline as possible.

While the type of plane may depend on availability and cost, there do seem to be preferred heights and speeds depending on the survey objectives. For targeting right whales only most surveying is done at about 230 m (750 ft) and about 185 km/hr (100 knots). AMAPPS, which targets multiple species, flies at about 183 m (600 ft) and about 200 km/hr (110 knots). Heights may also vary depending on local conditions and FAA regulations for the survey area. Distance from shore is also an important consideration for safety for reasons when selecting the type of plane (twin engine planes, although more expensive, should be used for surveys far off shore).

Table 2. Aspects of some studies that have used aerial surveys for cetaceans.

Study	Location	Aircraft	Transect design	Target/ average altitude (m)	Target/ average speed (km/h)	Improving detectability and species ID
Whitt et al. (2013)	New Jersey	Skymaster 337	Double saw-tooth	230	220	Photography
Taylor et al. (2014)	Cape Cod	Skymaster 337 O-2	Parallel	305	185	Continuously operating belly camera; circle-back
NEFSC & SEFSC (2013) (AMAPPS)	Western Atlantic	Twin Otter	Saw-tooth	183	200	Two independent teams; circle-back
Strindberg et al. (2011)	Gabon	Cessna 182	Saw-tooth	226	193	Circle-back
DiGiovanni and DePerte (2013)	New York Bight and mid-Atlantic	DeHavilland Twin Otter	Parallel	183	185	Two independent teams, circle back and belly window
Leeney et al. (2009)	Cape Cod Bay	Skymaster 337	Parallel	229	185	Circle-back, photography
Panigada et al. (2011)	Northwest Mediterranean	Partenavia P-68	Parallel	229	185	Circle-back, photography

Shipboard surveys

Surveys by ship are the other primary visual method of whale detection. One advantage of shipboard surveys is that greater time can be spent in the animals' habitat than can be spent during aerial surveys. This results in a greater chance of detecting individuals that may dive for long periods. However, the tradeoff is that shipboard surveys are much slower than aerial surveys and therefore, it requires much more time to cover an area with a ship versus a plane. As with aerial surveys, shipboard surveys as practiced by various researchers differ in ships used, transect design, observer height above sea level, speed, and methods for addressing imperfect detection (Table 3).

No standard ship type or size exists for conducting cetacean surveys (Table 3), and the variation in ships used most likely reflects budgetary constraints, ship availability, distance from shore, and other needs, such as corollary acoustic surveys, habitat studies, or studies of other marine organisms. However, ship size can greatly influence survey design and potentially effectiveness. Large ships can go farther offshore and to deeper waters, and perch observers higher off the water, while small ships may be able to survey in nearshore areas that larger ships may not be able to access. Despite the acknowledged need in statistical analysis of shipboard survey data to account for whale movement away from ships or attraction to ships (Palka and Hammond 2001), no full analysis of the tradeoffs in choosing a small vs. large ship is available to our knowledge. Perhaps more importantly, the acoustic properties or noisiness of a ship is also a consideration when deciding on a platform. However, studies on animal attraction to or avoidance of ships with different noise levels and of different sizes have shown a variety of results and may be different for different species (Corkeron 1995, Nowacek et al. 2004, DeRobertis et al. 2010). In some cases a smaller ship might be quieter, but not always, as NOAA's new survey vessels, including the one used for AMAPPS, were designed to be acoustically quiet to International Council for the Exploration of the Sea standards. Also, it may not be possible to choose a vessel with a low noise level but it is worth consideration.

Table 3. Aspects of some shipboard surveys for cetaceans. All species were targeted unless otherwise specified.

Study	Location and any target taxa	Ship type and size	Transect design	Observer height above sea level	Target/ average speed	Additional Methods to improve detectability and species ID
Whitt et al. (Geo-Marine, Inc. 2010, 2013)	New Jersey	45-m research vessel	Double saw-tooth	10 m	10 knots (~18.5 km/hr)	Photography
NEFSC & SEFSC (2012) (AMAPPS)	Western Atlantic	63-m research vessel	Saw-tooth	11.8 m and 15.1 m	10-12 knots	Two independent teams; transects interrupted, used towed acoustics, quiet vessel
Silva et al. (2003, 2009, 2014)	North Atlantic	12-m yacht 10-m motorboat	Saw-tooth	Varied	5 knots (yacht) 9-11 knots (motorboat)	Yacht: No interruptions Motorboat: Transects interrupted to confirm group size or species identification
Swartz et al. (2003)	Caribbean Sea	Not specified	Targeted	Not specified	10 knots	Pairing with towed acoustics; transects interrupted
Oleson et al. (2007)	Southern California; blue whales	38-m research vessel	Targeted	5.6 m	Not specified	Pairing with towed acoustics; transects interrupted; photography
Barlow and Taylor (2005)	North Pacific; sperm whales	53-m research vessel	Line transects; design not specified	10 m	Not specified	Pairing with towed acoustics; transects interrupted

Opportunistic observations

Whale sightings that are not a part of a formal survey design can also provide important data that can augment and support formal monitoring. In New York whale watching cruises by Gotham Whale provide information on presence and behavior of whales in the NY Harbor area, while cruises by The Coastal Research and Education Society of Long Island (CRESLI) provide this information for whales seen off of the east end of Long Island in local trips and farther afield in offshore trips. While both of these organizations conduct cruises primarily during the spring and summer as weather permits, during this time they are out much more frequently than most formal survey efforts could afford to be. Past efforts have shown a recent increase in humpbacks in around the entrance to NY Harbor and other trends in occurrence and behavior (P. Sieswerda, personal communication). Additionally, stranding data collected by the Riverhead Foundation for Marine

Research and Preservation can provide information about whale occurrence, threats and causes of mortality, and emerging health issues for whales. Finally, tools for the public to report observations like iNaturalist (www.inaturalist.org) can provide useful data outside the bounds of formal monitoring. All of these activities have the potential to persist for the long term and engage the public in monitoring and conserving whales in the NY Bight. Though we do not discuss opportunistic sightings in the comparison table or options section, we suggest that collaborating with these organizations, exploring citizen science tools, and integrating these opportunistic observations should be discussed as planning moves forward.

Visual methods compared and combined

Based on discussion at the expert workshop, it seems that the fundamental trade-off in choosing between the two visual methods is coverage of space versus coverage in time—aerial surveys maximize the area covered for the time available, while shipboard surveys maximize the time spent within the animals' habitat. Thus, aerial surveys provide a "quicker" snapshot than do shipboard surveys. This trade-off of extensive efforts vs. intensive efforts is an important consideration in any biological survey design, and with whale surveys it manifests itself mainly in the greater potential for missing diving animals when surveying quickly by plane. Beyond this basic difference, however, there are additional differences between the two platforms, nicely summarized by Panigada et al. (2011) (Table 4). Of these, the most important considerations for NYS DEC are the ability to combine towed acoustic arrays when surveying with ships, severe winter weather favoring aerial surveys for their ability to make quick use of periods of good weather, the higher potential for fatal accidents with airplanes (S. Kraus, personal communication), and the ability to collect associated environmental samples from ships (e.g., plankton samples). Also, aerial surveys may be able to cover the entire area of the Bight once or twice a month. Given the size of vessel likely to be available for contract (within a reasonable price range) the shipboard survey would have to be done less frequently—perhaps one or two times per season. The smaller the vessel the more likely it will also lose days to poor weather, especially in the areas farther offshore. During the winter aerial surveys are the visual method of choice for most researchers.

Table 4. Comparison of vessel (shipboard) and aircraft (aerial) survey methods for cetaceans in the Mediterranean Sea. Adapted from Panigada et al. (2011).

Vessel	Aircraft
Area covered	
Small vessels: nearshore, coastal waters, offshore (more limited by bad weather and endurance may be less than large vessels) Large vessels: coastal waters, offshore	Can cover up to about 500 miles; when working farther out to sea will have limited working time but is possible, depending on fuel capacity/endurance and proximity to airports
Travel speed around 10-12 knots limits area coverage with time	Travel speed around 100 knots means around 10 times greater search distance with time
Poor for areas with complex coastlines and small islands	Deals with complex coastlines and small islands well
Species	
Better at detecting species that may be diving for long periods of time	Better suited to the animals with shorter dive times given speed of platform; not good for species that are far offshore only given endurance limitations
Need to account for potential responsive movement	Responsive movement not a problem
School size estimation for some species can be difficult	Generally easier to estimate school size
Poor for estimating megafauna such as sea turtles,	Good for other megafauna (e.g. sea turtle, giant devil

Vessel	Aircraft
rays, sharks and tuna.. Good for observations of other cetaceans and seals.	ray, sharks, tuna) at least in the Mediterranean, ships, fishing gear
Environmental conditions	
Cannot operate in 'unacceptable' conditions (these will depend on species) – swell can be a major problem for detecting whales	Cannot operate in 'unacceptable' conditions (these will depend on species) – swell may be less of a problem for detecting whales
Given speed limitations, relatively poor use of good weather windows, this is more of an issue during the winter	Efficient use of good weather windows (higher survey speed, ability to move to good weather areas quickly)
Data collection	
Measurement of key parameters, especially distance, and to a lesser extent angle, is problematic but improving with new technology	Measurement of perpendicular distance easier and better
Estimation of g(0) using double platform methods well established and space on board usually not a problem	Difficult to use double platform methods in smaller planes (for some species 'circle back' works) but possible in larger planes
Allows collection of additional data: acoustic, environmental conditions, photo-identification data	Collection of additional data difficult or impossible but good for photo ID
Usually can incorporate more scientists	Limited number of scientists for smaller planes
Cost	
Offshore surveys more expensive than aerial surveys but can operate for longer periods of time on high seas; can collect additional data; nearshore surveys in small boats may be more cost effective.	More cost-effective where they can operate and better able to take advantage of good conditions when they are scarce (both geographically and seasonally), some additional data such as SST can be collected when using twin engine planes.

Passive acoustic methods

Acoustic detection techniques for cetaceans emerged in the 1990s as an alternative and/or complement to traditional visual survey methods. As with other animal groups for which acoustic surveys are frequently conducted (e.g., songbirds, frogs), acoustic detection techniques began to be used for whales because of the recognition that visual surveys have several important limitations (Mellinger et al. 2007): 1) they can be conducted during daylight hours only; 2) they are subject to enormous bias in poor weather or with rough seas; 3) animals are not "available" for detection when they are diving, as many large cetaceans do for long periods; and 4) the often limited spatial and temporal scale of surveys may not match the large ranges and unknown temporal movement patterns of whales. Acoustic detection methods, conversely, may be deployed in all weather conditions and all times of day, may detect animals in all depths, and may provide year-round data with limited additional effort beyond data processing needs. They are subject to a different "availability" concern, however, namely that only vocalizing animals are detected. Further, automatic detection algorithms, necessary for rapid processing of large acoustic recordings, are not yet available for all species, though this is an active area of research. Below we cover some of the primary acoustic monitoring methods and discuss their advantages and disadvantages.

Acoustic methods are divided into "passive" and "active" methods. Active methods involve the transmission of sound whose return echo can be analyzed to determine the identity and/or abundance of target organisms (Mellinger et al. 2007). These methods are rarely used in cetacean surveys except to gather information about prey items such as copepods and krill. Passive acoustic methods "listen only," meaning that no sound is transmitted by the recorder. Passive acoustics devices can be divided into three categories: stationary bottom-mounted recorders, cabled hydrophones, and mobile hydrophones affixed to ocean gliders, drift buoys, or ships. Each of these has its advantages and disadvantages, well covered by Mellinger et al. (2007) and summarized below.

Bottom-mounted recorders are commonly used for cetacean surveys at many depths. The attractiveness of this approach is that once units are deployed, they may be left in place for several months or more, collecting continuous data. As stationary units, they can yield data that show how intensively the area around the recorder is used by calling whales, although whether that use reflects a single relatively stationary individual or many individuals moving through cannot easily be discerned (but see Marques et al. 2013). When recorders are placed in tight arrays design, they can allow calls to be localized, when precise locations are of interest. Broad arrays can provide information on how animals are using the area, including assisting in interpretation of behavior around the recorders. They can also provide information needed for relative abundance estimates.

Towing cabled hydrophones with a ship or ocean glider maximizes spatial coverage at the expense of intensity of effort in a single location, a tradeoff of time for space similar to that between aerial and shipboard surveys. This expanded spatial coverage may prove advantageous to cover a large area like the New York Bight. Towed arrays require ships to tow them, but they can be piggybacked onto shipboard surveys with other primary objectives such as visual whale surveys, plankton surveys, and habitat mapping. Further, the pairing of acoustic and visual whale survey data can be powerful for a comparison of methods. AMAPPS uses towed hydrophones mainly for toothed whales including sperm whales, whose higher frequency vocalizations can be heard above the ship noise because of the speed of the ship. Towed hydrophones yield little information on baleen whales due to the flow of water masking much of the low frequency content within the sound recording (S. Van Parijs, personal communication).

Autonomous underwater vehicles (a.k.a. "gliders") can carry hydrophones over long distances and multiple depths, and represent a good option for passive acoustic monitoring in deeper waters and when wider coverage of space is desired than can be achieved with bottom-mounted recorders (Klinck et al. 2012, Baumgartner et al. 2013a). They are likely to be considerably cheaper than both bottom arrays and towed arrays (resulting from much less ship time) while gathering better information on baleen whales than towed arrays. NOAA's Northeast Fisheries Science Center, in collaboration with Woods Hole Oceanographic Institution, is implementing a three-year project to make both electric and wave gliders a more viable option for baseline monitoring. Wave gliders are the best option for monitoring at a large spatial scale such as the area of the NY Bight because electric gliders do not have enough battery life to cover the whole area. While the technology is new, the system has been successfully demonstrated in three field studies so far (M. Baumgartner, personal communication) and has promise for autonomously surveying the very large study area of the NY Bight year round.

The most frequently expressed concerns with the use of passive acoustics are 1) the difficulty of obtaining absolute abundance data, owing to imperfect knowledge of vocalization rates (and variability due to behavior, season, and sex); 2) the potential for missing animals that are not vocalizing; and 3) the additional sampling needed to obtain precise location data when that is of interest. However, regarding abundance estimates, as noted above, analytical methods are being developed for single recorder setups (Marques et al. 2013), broad arrays of passive acoustic recorders can yield relative abundance estimates (S. Van Parijs, personal communication), and knowledge of vocalization rates is increasing, which will eventually enable improved abundance estimates. Regarding missing animals, all survey methods miss some animals, and passive acoustic methods miss fewer animals than visual methods in many circumstances (Swartz et al. 2003, Barlow and Taylor 2005, Oleson et al. 2007, Clark et al. 2010), especially during winter when bad weather may significantly hamper or prevent surveying using planes or ships. Finally, triangular arrays can allow localization of calls (Mellinger et al. 2007) with a modest increase in equipment and effort. Whether precise location data are even needed depends on the objectives of a given study, and for NYS DEC's immediate purposes, presence within a larger management unit of, say, 30 arc-seconds × 30 arc-seconds (approximately 1 km × 1 km), a commonly used cell size for density modeling (e.g., Geo-Marine, Inc. 2010), is likely sufficient.

Tagging and telemetry

In recent years, tagging has increased in popularity as a method of tracking individual whales and has yielded insights into movement patterns (including residency times), depth profiles, and vocalization behavior (e.g., Mate et al. 1997, Wade et al. 2006, Friedlaender et al. 2009, Parks et al. 2011, 2012). Two primary kinds of tags are used: archival tags, which are attached with suction-cups and require tag recovery for data download, and satellite tags, which are usually injected into the blubber and underlying muscle for long-term data collection and are not recovered. Archival tags (e.g., DTAGs or Acousonde tags) usually include sensors such as three-dimensional accelerometers and magnetometers, depth sensors, and sound recording, providing a wealth of very detailed data on the whale's behavior including information on vocalization rates. Data from satellite tags must be relayed using a satellite link with limited bandwidth (typically the ARGOS system) and therefore the amount of data that can be transmitted is reduced (in most cases limited to location of the animal). Some tags combining both archival and satellite tracking capabilities are also available (S. Parks, Appendix A).

Both archival tagging and satellite tagging are research tools that will be critical for addressing NYS DEC's longer-term monitoring objectives. Once baseline information on whale occurrence and abundance in the Bight and shipping lanes is obtained, satellite tagging would provide useful data on individual whale movements and yield insights about the animals' behavior and residence time in our waters. Archival tagging will also provide behavioral information, like depth profiles and vocalization rates (which can be used to calibrate abundance estimates from acoustic monitoring), and facilitate health and population genetics studies. However, these methods do not appear to be appropriate or cost-effective for obtaining baseline information on seasonal occurrence and abundance. Sample sizes for tagging efforts are typically small (often fewer than five animals) and extrapolation from small sample sizes to an entire population is usually unadvisable. Further, for species that are determined to be using the Bight primarily for migration, a satellite tagging effort with a regional focus would be more appropriate. Tagging should certainly be considered when choosing techniques to conduct behavioral and movement studies, and may be piggybacked on shipboard surveys so that dedicated tagging cruises are not needed.

On the horizon

Here we briefly mention some promising techniques that are not yet ready to be deployed in baseline, multispecies, broad-scale monitoring, but that may be worth reconsidering in years to come. These include unmanned aerial vehicles, satellite counts, and automatic detection of whale blows. Unmanned aerial vehicles (which may refer specifically to either unmanned aircraft systems (UAS) or drones) have received a fair bit of attention in recent years for photography and other ecological monitoring (e.g., Iv et al. 2006, Koh and Wich 2012, Anderson and Gaston 2013), and have been tested with some marine mammals (Maire et al. 2013). They are being used currently by a group of researchers (including NOAA's SWFSC; https://swfsc.noaa.gov/news.aspx?id=18612) in New Zealand to look at sperm whales; they may also be able to take samples of the whale's plume with the drone in the future. For full consideration as a method of monitoring whales in the Northeast U.S., however, researchers must wait for the legality of operation over coastal zones to be assessed by the Federal Aviation Administration (S. Kraus, personal communication). Further, algorithms for automatic detection of marine mammals are lacking, and they lack the easy flexibility of aerial surveys for going "off effort" to count and identify aggregations of animals (S. Kraus, personal communication). Additionally, both drones, which do not require a pilot and UAS, which can operate autonomously but are monitored by a pilot who can take control if needed, still have a number of technical issues that need to be worked out. Other researchers have begun using existing remote-sensing technology, namely satellites, to count whales (Fretwell et al. 2014). Fretwell and colleagues report on some initial success in building detection algorithms for southern right whales (*Eubalaena australis*). Similar detection algorithms would need to be built for western North Atlantic species, and the technique's probability of detection and other parameters elucidated, before this method would be ready to deploy in our area.

Another method that has been considered for over the past 15 to 20 years with some promise is the automated detection of whale blows from infrared thermal imaging (Burkhardt et al. 2012, Santhaseelan et al. 2012, Zitterbart et al. 2013). Currently this method cannot identify whales to the species level, is not effective in windy conditions, and is less effective in warm summer when differences between air and blow temperatures are smaller, but it could alert visual observers to the presence of whales. Thus, they are mainly a tool to increase detectability or alert managers that whales are present. Considerable field testing is needed before this method could be deployed at a large scale for monitoring individual whale species.

Method comparison

In this section we lay out the advantages and disadvantages of each whale survey method. In doing so, we draw from a matrix generated during discussion at the expert workshop (Appendix A—workshop notes), workshop presentations (e.g., Rosenbaum and Camhi), and reports and published literature. The balance of advantages and disadvantages of individual methods (Table 5) should help inform a decision on the most suitable combination of methods for monitoring whales in the New York Bight.

Table 5. Comparison of whale survey methods, based on presentations and discussion at the January 2014 workshop and subsequent conversations; some of the contrasts were gleaned from Rosenbaum and Camhi (Appendix A). Dashes indicate that a particular piece of information is not applicable to the technique.

Method category	Method	Summary of advantages	Summary of disadvantages	General suitability for addressing these aspects of occurrence: Localization	Seasonality of occurrence	Distribution and abundance	Behavior
Visual	Aerial	Distribution & abundance estimates; the more cost effective of the two visual methods.	Provide a snapshot only; observations limited to daylight hours & good weather; especially challenging in winter, only surfacing animals are detected; observer error a factor; abundance estimates need lots of data (as do shipboard surveys); human safety a concern	Excellent	Varies based on monitoring intensity	Excellent—but requires a lot of data (as do shipboard surveys)	Very good for surface behavior (especially for seeing feeding and mothers with calves)
Visual	Shipboard	Distribution & abundance estimates; greater chance of observing long-diving whales, additional biological and oceanographic data collection can be included	Provide a snapshot only; observations limited to daylight hours & good weather; only surfacing animals are detected; observer error a factor; abundance estimates need lots of data (as do aerial surveys); more expensive than aerial	Excellent	Varies based on monitoring intensity	Excellent—but requires a lot of data (as do aerial surveys)	Excellent for surface behavior
Tagging	D tagging	Provides information on movement patterns and behavior, including vocalization behavior which can provide information to assist analysis of PAM data	Data collection is short term	-	-	-	Excellent

Method category	Method	Summary of advantages	Summary of disadvantages	General suitability for addressing these aspects of occurrence: Localization	Seasonality of occurrence	Distribution and abundance	Behavior
	Satellite tagging	Provides information about residency times and habitat use; good spatial and temporal coverage (individual)	Hard to get a large enough sample size needed to infer population-level movements; limitations in tag longevity	Excellent	Very good	-	Very good for traveling or migration and depth changes but fair to poor for other behaviors
Passive acoustics	PAM in general	Good for seasonal presence, occupancy; long and continuous data series; good temporal coverage; diel coverage; not weather dependent; permanent acoustic record; auxiliary species and environmental noise	Limited to vocalizing animals; limited spatially (depending on no. units); limitations for overall abundance estimates (relative abundance for some species)	Varies depending on detection range and array design	Excellent	Varies but generally poor; methods are in development	*Baleen*: Good *Sperm*: Excellent
	Bottom-mounted recorder (single)	Round-the-clock monitoring; ability to do simultaneous broad spatial coverage	Imprecise locations	Fair but likely adequate	Excellent	Fair	*Baleen*: Good *Sperm*: Excellent
	Bottom-mounted recorder array	Precise locations and relative abundance estimates may be possible; cost-effective	Additional recorders and deployment costs	Excellent within detection range	Excellent	Good	*Baleen*: Good *Sperm*: Excellent

				General suitability for addressing these aspects of occurrence			
Method category	Method	Summary of advantages	Summary of disadvantages	Localization	Seasonality of occurrence	Distribution and abundance	Behavior
	Glider	Many of the same advantages as PAM. presence, long and continuous data series, not weather dependent, information about depth profile of whale habitat use; real-time data reporting	New technology	Fair but likely adequate	Varies depending on monitoring intensity	Fair	*Baleen*: Good *Sperm*: Excellent
	Ship-towed hydrophone	Piggybacks on shipboard surveys	Not usable in shallow water; hard to hear baleen whales	Fair; only for deeper water	Varies depending on monitoring intensity	Fair	*Baleen*: Poor *Sperm*: Excellent

Examples of method combinations

Cetacean researchers have long recognized that each survey method has its advantages and disadvantages, and that methods deployed in combination yield better estimates of occupancy, density, abundance, and most other population parameters of interest. Most combinations of methods that are deployed have the goal of generating spatially explicit density estimates that cover surveyed and unsurveyed portions of the study area. In this section we summarize some combinations of methods used recently by efforts with similar goals to those of NYS DEC's.

Western Atlantic

In 2010, NOAA kicked off the Atlantic Marine Assessment Program for Protected Species (AMAPPS), a broad-scale monitoring effort aimed at providing data on the population status of marine mammals, sea turtles, and seabirds along the U.S. portion of the western Atlantic. The program includes aerial surveys, shipboard surveys, passive acoustics, and many auxiliary efforts. Because the goal of these surveys is to estimate regional abundance and distribution, New York waters are not covered thoroughly enough to assess whale populations in the NY Bight alone. AMAPPS includes three aerial tracklines fully contained within the New York Bight which are surveyed twice a year. Additionally, some shipboard transects are done in the NY Bight but, these are currently confined to deep water areas around the shelf break. However, AMAPPS program scientists have expressed a willingness to work with NYS DEC to provide some extra coverage, such as adding aerial tracklines in the Bight similar to their denser tracklines in BOEM wind energy areas south of Massachusetts and Rhode Island, off of southern NJ, and off of VA. Tracklines could be added in time for the winter 2014 survey (D. Palka and S. Van Parijs, personal communication). However, funding to continue AMAPPS in future years is uncertain though possible.

New Jersey

New Jersey (Geo-Marine, Inc. 2010, Whitt et al. 2013) conducted cetacean and sea turtle surveys using aerial, shipboard, and passive acoustic methods in 2008 and 2009 off the portion of the New Jersey coastline deemed most suitable for offshore wind development. Aerial transects followed NOAA methodology, using a double saw-tooth pattern that allowed coverage of the entire study area in a single day. Surveys were conducted monthly with two observers. Shipboard methodology used a single platform with three simultaneous observers and line transect methods following Buckland et al. (2001), also in a double saw-tooth pattern. Four to five bottom-mounted recorders were deployed generally in a diamond or cross pattern located in the central portion of the study area (see Geo-Marine, Inc. 2010 for deviations). Sample rates were set to target either delphinids or baleen whales.

Animal densities for the study area were estimated using conventional distance sampling techniques and finer scale densities were estimated using density surface modeling and general additive models, both in the program Distance (Thomas et al. 2010). Estimates were calculated separately for aerial and shipboard surveys. Passive acoustic monitoring results were used to supplement presence/absence information for certain species.

Over the two years of surveying, covering over 12,200 km of aerial trackline, over 12,800 km of shipboard trackline, and 38,700 hours of acoustic data collection, three endangered great whale species were detected: right whale (two on-effort sightings, shipboard and acoustic only), humpback whale (10 sightings, aerial and shipboard only), and fin whale (27 sightings, all three methods). The number of detections of any individual species was insufficient for the generation of density estimates by season, so seasons and/or species were pooled for density estimation. Aerial surveys produced so few detections of endangered whales that none of the density estimates for endangered whales included aerial data. Fin whale was the only species with sufficient data for modeling of pooled-season density.

European Atlantic

Hammond et al. (2013) report on a cetacean survey in the European Atlantic that repeated surveys conducted 11 years prior. The study area was divided into survey blocks, some of which were surveyed by ship, while others were surveyed by aircraft. Their shipboard surveys used a double platform approach (Laake and Borchers 2004) to generate abundance estimates and account for imperfect detection of animals. Aerial surveys employed the circle-back method (Hilby 1999) for this purpose. As the target of surveys was primarily smaller cetaceans like dolphins and porpoises, rather than larger whales to be targeted in New York, we may wish to draw limited conclusions about the suitability of these methods for our purposes in New York.

Approaches for baseline monitoring in the NY Bight

Guiding principles

In coming up with options for combinations of methods to meet New York's baseline information needs on large whale SGCN, we followed some guiding principles in addition to considering the objectives stated above. We determined that any baseline monitoring program for the NY Bight, to meet the minimum information needs, must

- Yield data on distribution, abundance (when possible), and seasonal and interannual varibility for each of the six species of large whales at a fine enough scale for management applications and conservation planning;
- Be conducted for a minimum of three years to provide a snapshot, but serve as a basis for long-term monitoring which ideally would continue to take place annually thereafter due to considerable interannual variation in the parameters of interest;
- Take advantage of existing data; and
- Coordinate with regional and neighboring-state monitoring programs and others, including cost and/or equipment sharing.

Monitoring options

In this section we lay out a variety of options for a minimum three-year SGCN whale inventory of the New York Bight that can provide data for assessment and to serve as a basis for guiding longer-term monitoring, guided by the principles above. Options are shown first for the targeted effort in the shipping lanes followed by options for the broad-scale survey of the Bight. We consider visual-only methods, passive acoustics-only methods, and combinations of visual methods with passive acoustics. Our aim was not to be exhaustive, but to present reasonable combinations of methods to meet New York's current information needs.

Shipping lane monitoring options

This piece of the monitoring program will be coordinated and combined with broader scale survey efforts such as aerial, shipboard surveys and gliders. Additionally, combining data from bottom-mounted recorders placed strategically with glider coverage for the full spatial extent, we expect to be able to get an acceptable acoustic profile for both spatial scales. Our plan for this monitoring is to begin with a baseline study and then scale up the surveying and conservation efforts as warranted by the results. As the DEC goes through this process, collaborations and funding from sources outside the agency will be necessary. Some collaborators may include the Port Authority of NY/NJ, the US Coast Guard, NOAA, professional mariners groups and others.

Subsequent steps that may be taken if the baseline data show recurring presence of whales, especially right whales, in the shipping lanes may include the following: 1) collecting behavioral data using other methods such as small-scale aerial and shipboard surveys (during which oceanographic and prey sampling could take place) as well as using tagging and telemetry; 2) determining the degree of overlap of whales and vessels in the shipping lanes (in collaboration with Port Authority and others); and 3) determining if real-time monitoring, additional speed restrictions and/or other means of mitigation are needed.

We considered three options for monitoring whales in and around the shipping lanes. In choosing an option it was necessary to balance costs and monitoring needs of both this and the broader scale surveying of the Bight. While three options are presented here, Option A is preferred as the best to meet our data needs as well as cost and logistical constraints. Therefore, we provide the most detail for Option A.

A. (preferred): Bottom-mounted recorders

The design for recorder deployment would be as follows (Figure 2):

- Three recorders would be placed at the convergence of the shipping lands at the entrance to New York Harbor.
- Recorders would be placed in, or in close proximity to, the Ambrose-Nantucket traffic lanes at a distance of approximately ~20 km apart starting from within state waters to just below Nantucket if funds permit (note: in Figure 2 we show recorders only to the edge of the Bight, which would be the minimum coverage required).
- Recorders would be placed in, or in close proximity to, the Ambrose-Hudson traffic lanes at a distance of ~20 km apart starting from within state waters to end of the continental shelf. Ideally, if cost allows, 2-3 recorders should be placed around the edges of the deepest part of the Canyon (near the shelf break) as this is an area of interest (note: again, these extra recorders are not shown in Figure 2).
- Placement of lines of recorders in the two shipping lands will also serve as "acoustic nets" to provide information on migrating animals, fitting into the broad-scale monitoring objectives.
- Data would be collected year-round for a minimum period of three years.

B: Bottom-mounted recorders and targeted aerial surveys

- Bottom-mounted recorders as described in Option A.
- Aerial surveys: Protocols would follow those detailed for the broader scale monitoring (below) but on a smaller spatial scale. Surveys should be conducted bi-monthly when possible. They should be conducted in the area of the shipping lanes, flights should follow a double-saw pattern or parallel transect pattern, and days should be randomly selected.
- Note: Even if this option is not employed at this spatial scale, broader scale aerial survey work should include coverage of these areas in the design so that the data can be compared and combined to whatever extent possible.

C: Bottom-mounted recorders, targeted aerial survey, and targeted shipboard survey

- Bottom-mounted recorders as described in Option A.
- Aerial surveys as described in Option B.

- Shipboard surveys: Protocols would follow those detailed for broader scale monitoring (below) but at a smaller spatial scale. Work should be conducted at least once per season (twice if possible) and coordinated with aerial survey work. Transect design will have to be decided with the consideration of high ship traffic in mind. Additional data should include oceanographic data and prey sampling if possible.

Broad-scale baseline monitoring options

As we did for the shipping lanes above, here we lay out a variety of options for a broad-scale baseline SGCN whale inventory of the New York Bight. Key findings are summarized in Table 6.

1. *Aerial only*

   Information generated on whale SGCN: Aerial surveys can be very useful for characterizing the distribution and abundance of some whale species. The New Jersey study (Geo-Marine, Inc. 2010, Whitt et al. 2013) got very little information from aerial surveys compared to shipboard and acoustics (A. Whitt and K. Dudzinski, personal communication), but this may have been because of the size of the survey area, the configuration of the airplane, or the possibility that New Jersey is primarily a migratory pathway for large whales, with no or few resident populations and aggregations that would have made visual detection more likely. Bimonthly aerial surveys in the NY Bight conducted by the Riverhead Foundation for Marine Research and Preservation (DiGiovanni Jr. and DePerte 2013) over the course of 13 months in 2004 and 2005 yielded multiple fin and humpback whale detections and a single detection each of sperm, sei, and right whales east of our identified study area. Relying on this method alone for NY would not likely provide sufficient information on sperm whales, which spend long periods in dives, or sei and blue whales, which appear to be rare in NY. With so few detections of many target species in these two recent surveys, plus feedback from the expert workshop about the difficulties and dangers of winter surveys, it appears that aerial surveys alone will not be sufficient to meet New York's basic information needs for many SGCN. Combining aerial surveys with other methods will be necessary.

   Compatibility with existing programs and data: Continuing aerial surveys in NY will have the benefit of meshing cleanly with AMAPPS regional surveys (and the potential for two surveys per year as a part of AMAPPS using a denser set of tracklines in the NY Bight, if AMAPPS is continued). Additional aerial surveys would also provide a comparison to the 2004-2005 surveys.

   Auxiliary information: Other marine mammals (including harbor porpoises), sea turtles, sharks, and other marine species may be detected with aerial surveys. For some of these species the numbers of detections may be sufficient to yield useful baseline information. NY-specific abundance estimates may be possible for the more common large whale species like fin and humpback. Other auxiliary data may include presence of vessels, fishing gear, dead and entangled whales, and in some cases environmental data such as sea surface temperature.

2. *Shipboard only*

   Information generated on whale SGCN: Shipboard surveys, like aerial surveys, have many benefits, and were rated highly in our expert workshop (Table 5). When used alone, however, they have some of the same limitations as aerial surveys alone, including the low expected frequency of encounter with sperm whales, which spend a great deal of time in dives, and blue and sei whales, which appear to be rare in our waters.

Compatibility with existing programs and data: Shipboard surveys in the Bight would complement regional data from AMAPPS and New Jersey's 2008-2009 surveys.

Auxiliary information: Shipboard surveys provide an opportunity for a wealth of additional data collection in addition to detections of non-target species during whale surveys. Many researchers use the shipboard platform to collect data on habitat, zooplankton, and fish schools (e.g., NEFSC and SEFSC 2013). Some of these data could lead to a better understanding of habitat relationships for whales and the eventual ability to monitor prey base and other parameters as predictors of whale occurrence and relative abundance (e.g., Pendleton et al. 2009, Gregr et al. 2013, Baumgartner et al. 2013b). The most important add-on for shipboard surveys for the purposes of NY's baseline whale surveying, however, is the opportunity to tow a hydrophone array for passive acoustic monitoring. The critical information obtained via this method for our stated goals is acoustic detection of sperm whales, which are less reliably detected with visual methods. In the 2011 AMAPPS surveys, acoustic detections represented 87% of all sperm whale detections (NEFSC and SEFSC 2012). NOAA is currently working on incorporating detection rates of sperm whales into abundance estimates (NEFSC and SEFSC 2013). However, the towed hydrophone arrays cannot be used safely in shallow waters and are useful for detecting baleen whales, so this approach would not yield important information for many species in much of the Bight.

3. *Passive acoustics only*

Information generated on whale SGCN: The biggest advantage of most passive acoustic methods over visual methods is the ability to conduct round-the-clock sampling over broad geographical areas in all weather conditions at a cost comparable to or less than that of aerial or ship board surveys. They appear to be as reliable as visual methods for identification of the six large whales, and have higher detection rates than visual methods. In fact, were NY's sole information need the daily occupancy (presence or absence) of large whales of the Bight at a coarse scale, passive acoustic methods could meet much of that need. The main limitation of passive acoustics at present for meeting NYS DEC's needs is that abundance estimates from non-arrayed recorders are presently poor, but could improve in the near future (see Marques et al. 2013). In addition, much of the useful visual observations of whale behavior, occasions of ship strike or entanglement, and other species presence would not be obtained.

A monitoring plan based solely on passive acoustics would entail at least one line of recorders (or preferably two, as in the design for shipping lanes above) extending southeast from Long Island as in the Cornell Lab of Ornithology (2010) study to serve as an "acoustic net" to determine migration timing, combined with a method of covering the entire Bight. A glider would be the most cost-effective method of doing the latter, although a coarsely spaced grid of bottom-mounted recorders would be another option.

Compatibility with existing programs and data: AMAPPS has a bottom-mounted recorder component (though not to date in the NY Bight) and the types of data and methods of data collection would be also be comparable with those in the Cornell Lab of Ornithology (2010) study. It would also be comparable to data being collected by the NEFSC and the New England Aquarium in Massachusetts. This could be also integrated into the regional Ocean Observing Program being developed by NOAA. The NEFSC and WHOI will be deploying a glider in the Gulf of Maine in 2015.

Auxiliary information: Toothed whales (in addition to sperm whales) may be detected if recorders' sampling frequency is set to cover their vocalizations' frequency range. Ambient noise levels, noise pollution, sounds from fish and other animals can also be detected. A towed hydrophone could be used if a shipboard survey is chosen to collect data on sperm whales. Currently, AMAPPS is using a towed hydrophone for shipboard surveying near the edge of the continental shelf, so data on sperm whales near the shelf should be covered by that effort for some seasons as long as funding continues.

4. *Aerial and shipboard*
   Information generated on whale SGCN: The combination of aerial and shipboard surveys would yield better distributional information and would balance the advantages and disadvantages of each method. The towed hydrophone array would yield good information on sperm whales in deeper water, but would not yield good information on baleen whales and could not be used near land due to safety concerns. Winter surveys would remain difficult to conduct and less trustworthy given inclement weather conditions.

5. *Aerial with passive acoustics*
   Information generated on whale SGCN: Aerial surveys could monitor changes in abundance while passive acoustics monitored changes in seasonality over time. Several of the expert reviewers felt that this option was the most cost effective.

6. *Shipboard with passive acoustics*
   Information generated on whale SGCN: This option accounts for the shortcoming of towed hydrophones (deeper water only) by using bottom-mounted recorders or an ocean glider throughout the Bight. The towed hydrophone could be tuned to detect sperm whales, with the bottom-mounted recorders targeting baleen whales.

7. *Aerial, shipboard, and passive acoustics*
   Information generated on whale SGCN: This combination of all four primary methods under consideration would be the strongest for generating information on whale SGCN, including the rarest species and those least easily detected. Several of the expert reviewers felt that this would be the best option if funds were not limiting.

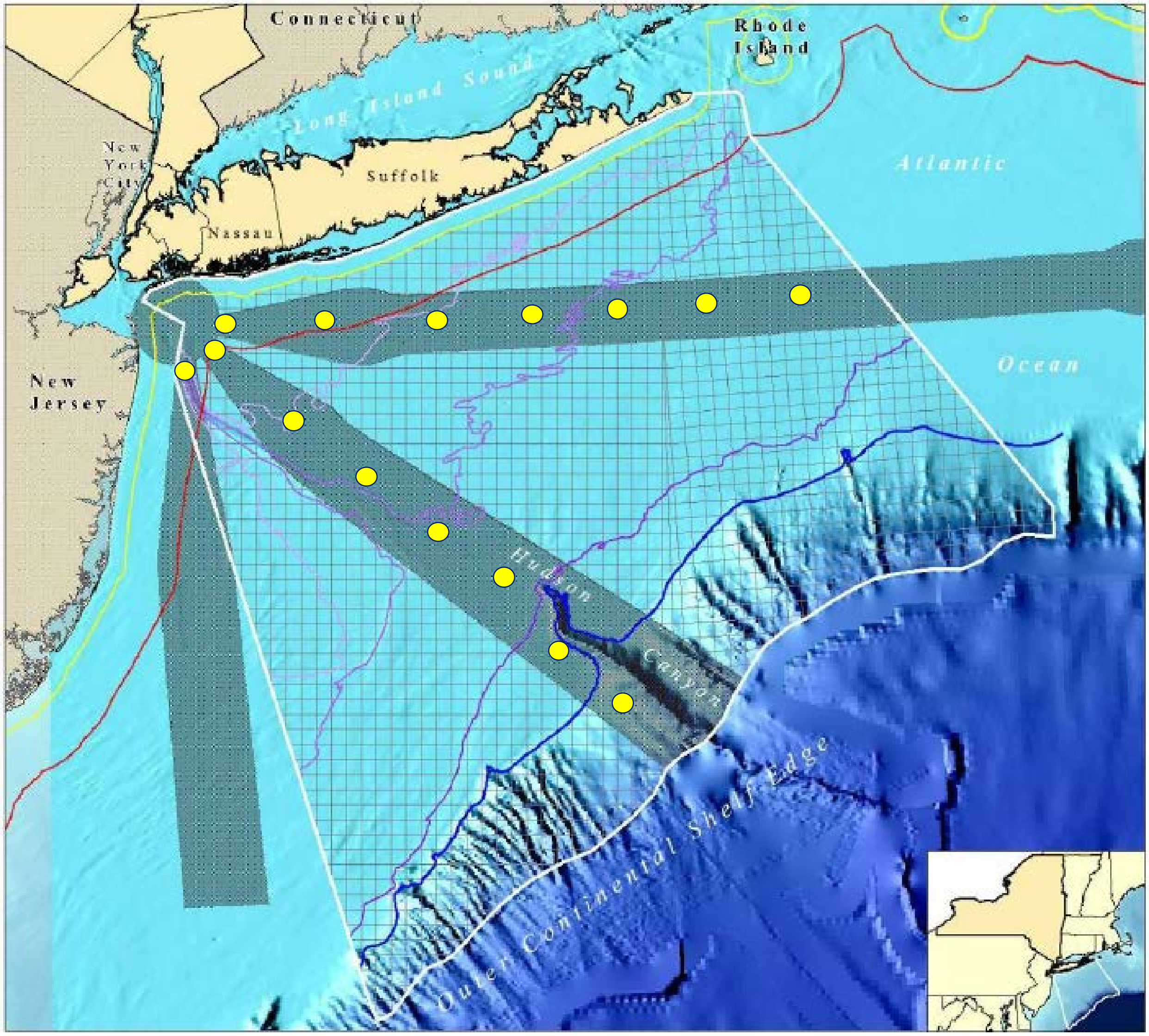

Figure 2. Mock-up, for illustration purposes only, of bottom-mounted recorder deployment to meet some baseline information needs on large whale SGCN. Recorders are represented by yellow dots; shipping lanes are gray swaths. The seven-recorder lines through the shipping lanes would serve to characterize distribution in the shipping lanes and serve as "acoustic nets" (Cornell Lab of Ornithology 2010) intended to capture migrating animals.

Table 6. Summary of key features of seven possible approaches to broad-scale baseline monitoring of SGCN whales in the New York Bight. We use "distribution" as shorthand for other facets of animal occurrence such as daily, monthly, or seasonal occupancy.

Approach	Likely data yields	Key shortcomings
1. Aerial only	Abundance and distribution of fin whales; distribution of humpback and right whales	Little information on sperm, sei, blue whales; winter data sparse
2. Shipboard only	Abundance and distribution of fin whales; distribution of humpback and right whales; with towed hydrophone, distribution of sperm whales	Little information on sei whales; without hydrophone, little information on sperm and blue whales; winter data sparse; no round-the-clock data closer to shore
3. Passive acoustics only	Year-round, relatively coarse-scale distribution and relative abundance of baleen whales, depending on the number and configuration of recorders; migration timing and patterns	Somewhat imprecise location data throughout most of the Bight (depending on the number and configuration of recorders); no abundance estimates possible in most places (although new methods are being developed); sperm whale data would be provided primarily by AMAPPS shipboard surveys with towed arrays
4. Aerial with shipboard	Improved estimates of abundance and distribution of fin whales; distribution of humpback and right whales; distribution of sperm and maybe blue whales; better chance at distribution of sei whales	Winter data sparse; no round-the-clock data closer to shore
5. Aerial with passive acoustics	Abundance and fine-scale distribution of fin whales; fine-scale distribution of humpback and right whales; year-round, coarse-scale distribution of all six species; winter abundance in key areas with arrays; migration timing and patterns	Likely little information on sei whales
6. Shipboard with passive acoustics	Abundance and distribution of fin whales; distribution of humpback and right whales; distribution of sperm and maybe blue whales; year-round, coarse-scale distribution of all six species; winter abundance in key areas with arrays; migration timing & patterns	Likely little information on sei whales
7. Aerial with shipboard and passive acoustics	Abundance and fine-scale distribution of fin whales; fine-scale distribution of humpback and right whales; year-round, coarse-scale distribution of all six species; winter abundance in key areas with arrays; migration timing and patterns	Possibly little information on sei whales (but best chance)

Recommendations and additional details

NY Natural Heritage worked with NYS DEC to narrow down the seven baseline options outlined above to three options that appeared to best meet New York's information needs and that spanned a range of likely budgets. Our preferred option for monitoring shipping lanes is Option A and that will not be discussed further here. Below we provide detail on sampling design and data collection for three options for conducting broad-scale monitoring. Cost estimates were provided separately to NYS DEC's senior managers and are not included here. In all three options, coordination with AMAPPS and the NEFSC/WHOI glider project will yield the most cost-effective and consistent approach to data collection. Preliminary conversations with NEFSC scientists suggest that it may be possible to add AMAPPS tracklines for the New York Bight for aerial surveys that NOAA would conduct approximately twice per year. Coordination on the design and deployment of bottom-mounted recorders is also possible.

Option 4: Aerial and shipboard surveys

- Relative cost: Middle of the three options
- Aerial surveys:
    - Survey design, method of data collection and safety considerations (including appropriate flying conditions) should be finalized in conjunction with staff from DEC and NOAA's NEFSC in order to have results that are comparable to existing NOAA surveys and to provide the best possible safety guidelines.
    - Surveys should be conducted at least once monthly (and as possible in winter). Sample days should be randomly selected during each month.
    - Flights should follow double-saw-tooth tracklines that are randomly generated.
    - Approximately 2500-3000 km of trackline will cover the Bight, depending on the angle between transect legs. If tracklines are flown at 185 km/hr, it should be possible to cover the Bight in three days, including flying to the start point and off-effort data collection. Expect surveys to be canceled due to inclement weather in one of every four days on average.
    - Surveys should be conducted from a standard altitude (e.g., 183 m or 230 m). The plane's position should be recorded regularly using GPS.
    - Aircraft should be twin engine with bubble windows or other means of all-around visibility.
    - A minimum of two observers should be used, one on each side of the aircraft. An additional observer serving as a data recorder is preferred, with observers rotating positions regularly. A belly observer or camera should be used to ensure no animals are missed on the trackline.
    - Data recorded should include species of whales sighted and angle from observer (time and position). Group size and any behavioral observations also should be recorded. The focus of the data collection should be on the six target species of large whales. However, additional data, including basic information on all marine mammals, sea turtles, vessels, fishing gear, other aircraft, and sea surface temperature should be collected as well.
    - Planes may go off effort and circle back to confirm identification of observed whales, count them, and take photo ID pictures of right whales.
    - Environmental data collected should include factors expected to affect detectability of whales (e.g., glare, water color, clarity, sea state, and weather) at the beginning of each track line and whenever there are changes in conditions.

- Shipboard surveys:
    - Surveys should be conducted once per season at minimum (preferably at the same time period as aerial surveys to help compare results).
    - The same tracklines used for aerial surveys may be used for shipboard surveys. With 2,500 km of trackline, and ship speed of 18.5 km/hr (= 10 knots), 135 hours (or 17 eight-hour days) would be needed to complete the tracklines. Expect surveys to be canceled due to inclement weather in one of every four days on average.
    - The focus of the data collection should be on the six target species of large whales. However, additional data, including basic information on all marine mammals, sea turtles, vessels, and fishing gear should be collected as well.
    - Surveys should be conducted from a standard height above the water, using a single- or double-observer platform.
    - A minimum of two observers should be used, one on each side of the ship. An additional observer serving as a data recorder is preferred, with observers rotating positions regularly.
    - Data recorded should include species of whales sighted and angle and distance from observer (time and position), as well as behavior and group size.
    - Ships may deviate from the trackline to confirm identification of observed whales count them, and photograph right whales for ID.
    - Basic environmental data should be collected including sea state, weather, sea surface temperature, and salinity.
    - Opportunities for corollary data collection (zooplankton abundance, towed hydrophone recordings in deeper waters, oceanographic data, biopsy) should be explored.

Option 5: Aerial surveys with passive acoustics

- Relative cost: Most cost effective of the three options
- Aerial surveys: As in Option 4
- Bottom-mounted recorders:
    - The preferred design would be one that maximizes coverage of the Bight and also specifically targets migrating animals. Given the objectives of our monitoring program we also have to consider coverage of the shipping lanes. To that end, we would ideally employ the design discussed in the options for the shipping lanes (Figure 2). Alternatively, only a single line (7 or 8 recorders) could be deployed as a means to document migration while using the aerial surveys to document Bight-wide occupancy, but this is less ideal as it would not give us baseline data in the shipping lanes.
    - Deployment will be year-round.
    - Recorders should be set to frequencies of baleen whale vocalizations (e.g., 2 kHz). If AMAPPS is not continued beyond 2014, additional recorders could be placed along the shelf break and tuned to the higher frequencies of sperm whale vocalizations.
    - Deployment and recovery of recorders would be by ship.
    - Data to be collected include daily presence, seasonal occurrence, approximate location, and sound level measurements (for determining acoustic masking).

Option 7: Aerial and shipboard surveys with passive acoustics

- Relative cost: Most expensive of the three options

- Aerial surveys: As in Option 4
- Shipboard surveys: As in Option 4
- Passive acoustics: As in Option 5

Data analysis, reporting, and aggregation

A full treatment of analysis of monitoring data and aggregation with existing data is beyond the scope of this report. However, here we offer some preliminary considerations of accounting for detection biases, as well as looking at some different approaches to habitat and distribution modeling. Finally, we discuss the aggregation of data to meet our objectives, including determining trends and identifying areas of conservation importance.

The last two decades have seen the emergence of a near-universal awareness of the importance of accounting for imperfect detection in the analysis of wildlife survey data. Survey targets are never detected perfectly; that is, some targets are nearly always missed despite being present at the site and available for counting during the survey. Further, the reasons for survey targets being missed are myriad: habitat type, observer differences, weather, and other factors may play a role. In whale surveys, glare, sea state, and observer fatigue are just a few of the factors that undermine our confidence in count data accurately representing abundance, or even in nondetection equating to absence. Luckily, statisticians have developed many analytical techniques that can account for, rather than ignore, imperfect detection in surveys to determine either presence or abundance, and these are constantly being refined. Distance sampling (Buckland et al. 2001, Marques et al. 2013) was designed with marine mammal surveys in mind, and takes advantage of the declining detectability of whales with increasing distance from the observer to model the distance-detectability function and use this to adjust density estimates. Occupancy modeling (Mackenzie et al. 2006) is an approach suited for presence/nondetection data such as those obtained from most passive acoustic monitoring. In both approaches, covariates for habitat, observer, weather, or other factors can be included. As stated earlier, any survey effort or combination of efforts deployed in New York must first try to maximize detectability, and secondly account for its still being imperfect (Taylor et al. 2014).

Results should be reported at the finest spatial and temporal scales supported by the data. Data on as fine a temporal scale as daily may be available and useful for some species using passive acoustics. Monthly density estimates in one-minute grid cells may be available for some species from aerial surveys, while seasonal or even annual presence estimates with lower spatial resolution may be the finest resolution possible for others, depending on detection frequency and precision. All survey data will be available to the NYS DEC and made publicly available as regulations permit.

Critical products of a three-year monitoring effort, beyond raw observations and maps of detections, include extrapolations of the findings to the entire study area. We recommend that any monitoring conducted in the New York Bight have an analysis component that facilitates Bight-wide decision making. Recognizing that observational data are incomplete and that various habitat and oceanographic parameters can predict whale abundance and distribution, researchers have used a variety of techniques to create distribution models and density surfaces from whale survey data (e.g., Geo-Marine, Inc. 2010, Becker et al. 2012, Gregr et al. 2013, Palacios et al. 2013, Lambert et al. 2014). Such efforts are most rigorous when based on systematic or randomized sampling as described here (but see Lagueux et al. 2010 for an example based on data from a variety of sources). In future years, armed with some additional data, modelers may attempt more mechanistic approaches that aim to describe ecological and oceanographic processes rather than comparatively simple correlative approaches (Palacios et al. 2013).

A minimum three-year monitoring effort should produce a useful snapshot of large whale species distributions in the New York Bight, and will yield a strong dataset for determining long-term change when additional data are collected in years to come. However, in the shorter term, as offshore energy and other projects are proposed, managers are in need of tools to identify important areas for whales in the Bight. For this purpose we will want to consider other recent available data, potentially including those data collected opportunistically as in citizen-science efforts. Such efforts are fraught with challenges. Of the two past efforts to do this for New York that we are aware of, one was based on a multiyear set of surveys of varying methodologies, anecdotal observations, and strandings (Sadove and Cardinale 1993), while the other was a compilation of sightings and survey data from an existing data clearinghouse, the North Atlantic Right Whale Consortium database (Lagueux et al. 2010, NYS DOS 2013). Both data sources were admittedly incomplete and included records from a variety of sources. That the two studies often yielded strikingly different results (Figure 3) is more likely due to varying methodologies and use of opportunistically collected data collection than to ecological changes in the 20 years separating the compilations, though we cannot be sure of this. Aggregating data from varying sources can be confounded by varying survey methods, survey effort, interannual and seasonal variation, and other factors. The identification of areas of conservation importance for whales will require considerable additional data collection and analysis, but certainly, the best estimates of important areas for whales in the New York Bight will only be as good as the data and methods used to identify them. With the monitoring effort outlined here, New York has the opportunity to collect consistent, reliable data through dedicated survey efforts that will inform baseline estimates and ideally result in lower impacts to the giants that share our waters.

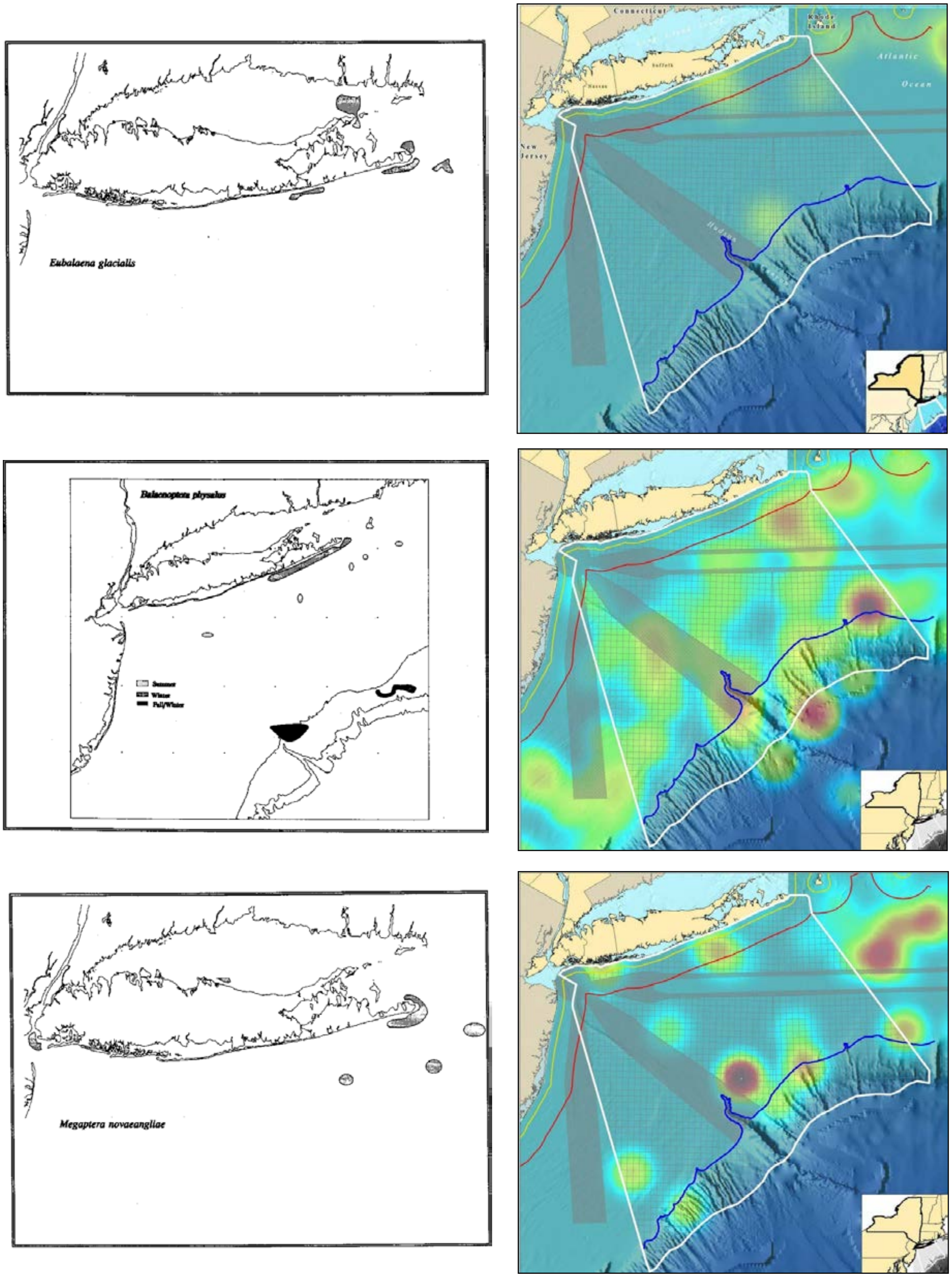

Figure 3. Maps representing "areas of occupancy and significant habitat use" (Sadove and Cardinale 1993; left) and models of annual relative abundance (NYS DOS 2013; right) for North Atlantic right whale (top), fin whale (middle), and humpback whale (bottom).

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Appendix A: Workshop materials

Documents from the January 2014 workshop are included in some versions of this report in the following order:

- Agenda (1 page)
- Participant list (2 pages)
- Meeting notes (13 pages)
- Presentations (232 pages):
  - M. Schlesinger
  - L. Bonacci
  - R. DiGiovanni
  - S. van Parijs
  - A. Rice
  - S. Parks
  - H. Rosenbaum and M. Camhi
  - D. Palka
  - T. Cole
  - A. Whitt
  - S. Kraus