OCEAN PLANNING IN THE NORTHEAST

Northeast Regional Ocean Council
Marine life Data and Analysis Team (MDAT) Work Plan

Marine Mammals and Sea Turtles

Pat Halpin, Jason Roberts, Jesse Cleary and Corrie Curtice

Duke University

Foreword

Work Plans for the development of products characterizing marine life distribution, abundance and trends were received from the Marine-life Data and Analysis Team (MDAT)[1] by NROC following approximately 12 months of discussion, review, and consideration by three Expert Work Groups, Regional Planning Body members, and many ocean planning stakeholders. These Work Plans contribute to Action 1-1 (i.e., creating new spatial data products of the distribution and abundance of marine life) under the Health Ocean and Coastal Ecosystems Goal in the Framework for Ocean Planning in the Northeast. The spatial data products that will result from these Work Plans will also contribute to NE RPB decisions on incorporating new data products into decision-making, as appropriate. For example, NROC is working with RPB members and agency representatives to understand how distribution/abundance and various types of aggregated or synthesized data products could be used in project siting, planning, permitting and various types of consultations. An option currently under consideration is for these distribution and abundance data products to contribute to the definition of "core areas" for species and species groups that then may be considered in the early phases of project siting and planning. Further synthesis of species and species group core area data products could result in maps of hotspots for single taxa (i.e., Marine Mammals, Sea Turtles, Birds, Fish) and then multi-taxa hotspots.

The MDAT Work Plans contain descriptions of the data sources, methodology, and resulting spatial data products that are being developed for Marine Mammals and Sea Turtles, Avian Species, and Fish Species. Resulting spatial data products include distribution and abundance estimates for various temporal windows derived from models that incorporate environmental/habitat variables, as well as a variety of "summary" data products: species groups, and metrics such as total biomass, species richness, and persistence. MDAT subgroups (Marine Mammals and Sea Turtles, Avian Species, and Fish Species) describe specific data products based on the characteristics of their individual datasets, methodology, and data availability.

NROC envisions that the detailed distribution/abundance map outputs for individual species and species groups could be used by agencies to develop opinions/decisions on specific projects at relatively fine scales. These products would be useful once potentially vulnerable species have already been identified for a particular project/action, and when understanding fine scale distribution/abundance at particular times of year is critical.

Forthcoming aggregate products, such as "core areas" for a species or species group (or eventually whole taxa and multi-taxa), could be used by project proponents, states, federal agencies, and the public to better understand and characterize siting issues early in the planning process for potential projects/actions.

[1]MDAT is a partnership between Duke University (PI Pat Halpin), the NOAA Northeast Fisheries Science Center (co-PI Michael Fogarty), the NOAA National Centers for Coastal Ocean Science (co-PI Brian Kinlan), and Loyola University (co-PI Earvin Balderama).

1 Introduction

The Marine-life Data & Analysis Team (MDAT) is working in concert with the Northeast Region Ocean Council (NROC) and the Northeast Regional Planning Body to aggregate data and model products that describe the distribution, abundance and trends of marine life in the Northeast. MDAT will provide well-documented, understandable and comparable products that will support future marine spatial planning needs that emerge from the region. The team is comprised of: the Marine Geospatial Ecology Lab (MGEL) at Duke University; the Center for Coastal Monitoring and Assessment Biogeography Branch at NOAA's National Centers for Coastal Ocean Science (NCCOS); the Ecosystem Assessment Program at the NOAA's Northeast Fisheries Science Center (NEFSC); and the Department of Mathematics and Statistics at Loyola University, Chicago (Loyola). MGEL is providing overall project management and integration functions, along with products for marine mammals and sea turtles. NCCOS and Loyola are creating models and products for avian species, and the NEFSC is creating models and products for fish species.

NROC and MDAT have assembled three expert working groups for each group of species (marine mammals and sea turtles, avian species, fish species). Each group has convened three times to review potential data sources, share expertise on specific species, discuss potential products, and review progress. The working groups will continue to meet and be kept apprised of progress throughout the project timeline, with final products being delivered by summer 2015.

This work plan summarizes the progress to date and incorporates work group feedback received on the geographic scope for all products, the specific species to be modeled and mapped, and existing data sources for marine mammals and sea turtles. This plan also presents information about the temporal extent, spatial resolution, data gaps, and methodology that will be used to develop new data products for marine mammals and sea turtles.

2 Geographic scope: Marine life assessment boundaries for the Northeast

The assessment boundaries for this project were determined by discussions between MDAT team members, the three expert work groups, representatives from the Mid-Atlantic Data Portal team and NROC staff (Figure 1). The resulting area includes Hudson Canyon and Long Island Sound in the southern portion and stretches to the Bay of Fundy in the north. Data product coverage within these bounds will be highly dependent on data availability, and will likely differ among marine life components. The spatial coverage and data limitations specific to each marine life component are described below.

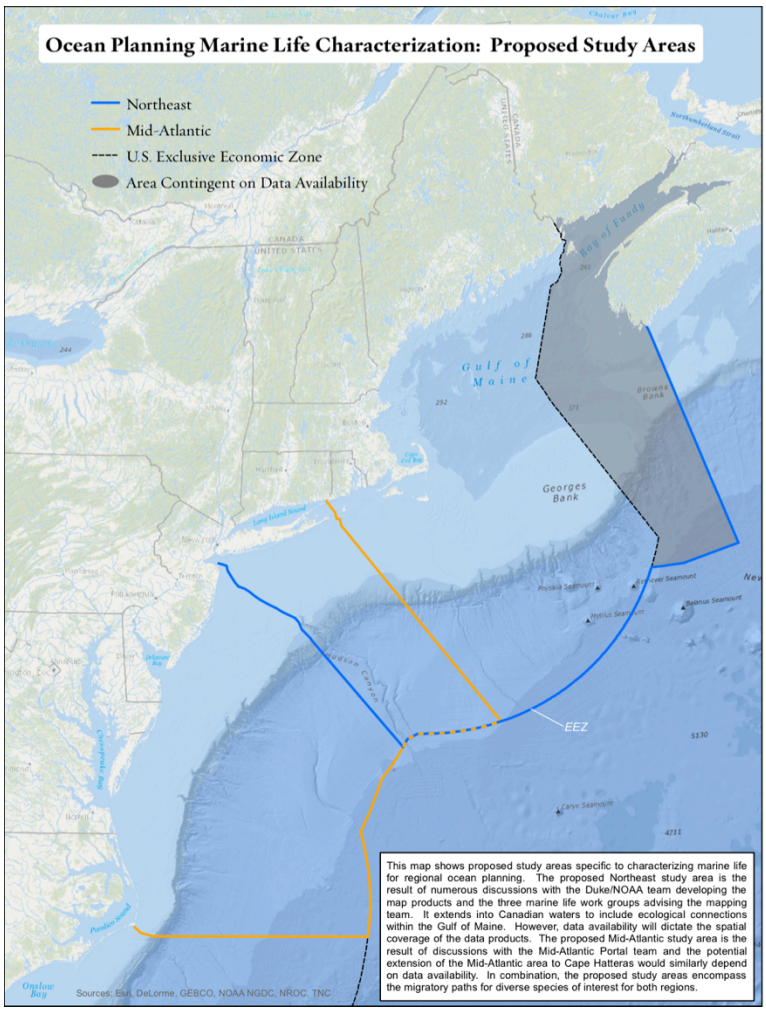

Figure 1. Geographic boundaries for marine life mapping in the Northeast, showing adjacent assessment area in the Mid-Atlantic region.

3 Marine mammals and sea turtles

3.1 Source data for marine mammals and sea turtles

Duke MGEL has compiled a database of line-transect data sources from multiple organizations, platforms (aerial and ship-based), and time periods (1992 – 2014) spanning the entire US East Coast and into Canadian waters (Table 1, Figure 2). Surveys that become available to Duke MGEL after products have been created for this NROC effort may be incorporated into the model process framework to produce updated products, based on available funding.

Table 1. Northwest Atlantic line-transect surveys used in marine mammal and sea turtle density models.

Surveys	Start	End	On Effort Length (1000s km)	Effort Hours	Survey Count
NEFSC Aerial Surveys	1995	2008	70	412	8
NEFSC North Atlantic Right Whale Sighting Survey	1999	2013	438	2366	24
NEFSC Shipboard Surveys	1995	2004	16	1145	6
NJDEP Aerial Surveys	2008	2009	11	60	2
NJDEP Shipboard Surveys	2008	2009	14	836	2
SEFSC Atlantic Shipboard Surveys	1992	2005	29	1764	6
SEFSC Mid Atlantic Tursiops Aerial Surveys	1995	2005	35	196	7
SEFSC Southeast Cetacean Aerial Surveys	1992	1995	8	42	2
UNCW Cape Hatteras Aerial Surveys (Navy)	2011	2013	38	250	4
UNCW Early Marine Mammal Aerial Surveys	2002	2002	18	98	1
UNCW Jacksonville Aerial Surveys (Navy)	2009	2013	132	805	10
UNCW Onslow Bay Aerial Surveys (Navy)	2007	2011	98	563	6
UNCW Right Whale Aerial Surveys	2005	2008	114	586	3
Virginia Aquarium Aerial Surveys (in progress)	2012	2014			1

The majority of the data was collected in summer months, with seasonal spatial gaps existing south of the Cape Cod area (Figure 1).

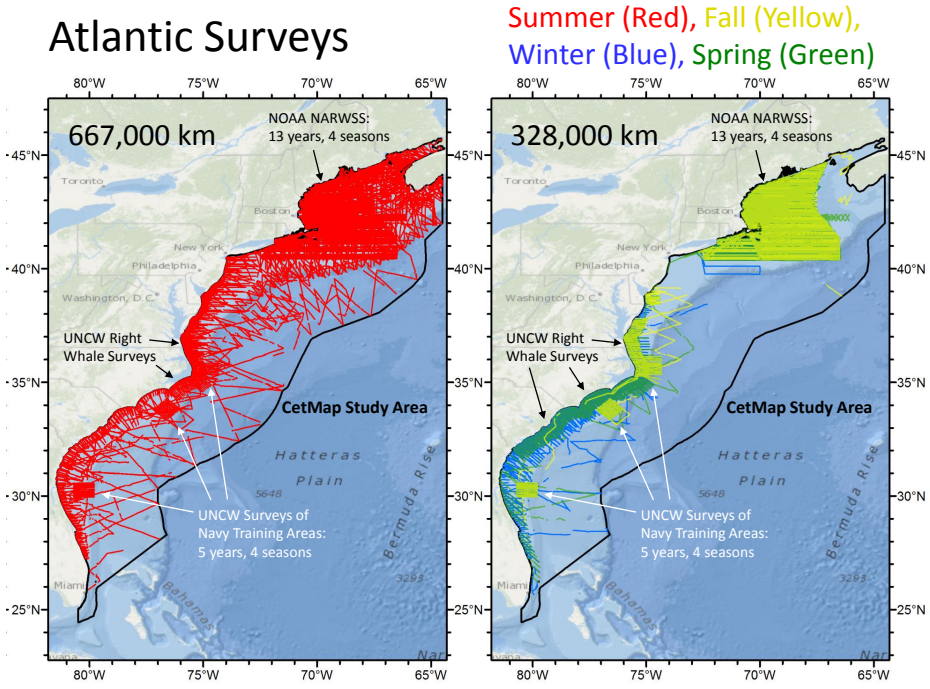

Figure 2. Survey effort and coverage for the US East Coast from data listed in Table 1.

3.2 Marine mammal/Sea turtle species and groupings

Duke MGEL has modeled marine mammal species, and will model sea turtle species, known to occur in the northeast region and that have sufficient sightings between Delaware Bay and the Bay of Fundy, either as an individual species or as a species group. For species with too few sightings in the northeast region, incorporating additional sightings beyond the focal region allows a model to be created and to predict into the region (Table 2).

Table 2. Cetacean, pinniped, and turtle sightings from the available datasets that occurred between Delaware Bay and the Bay of Fundy (39-45 °N, 64-75 °W) and are suitable for density modeling. n = number of sightings. Temporal Resolution is monthly, seasonally, or year-round based on the availability of data. Species flagged with a Model Group will not be modeled individually but as part of the designated group, due to insufficient sightings or ambiguous taxonomic identifications. All models are habitat-based (they predict density from environmental covariates) and may incorporate additional sightings north and south of the focal region, when appropriate.

Family	Scientific Name	Common Name	n	Temporal Resolution	Model Group
Cetaceans	Balaenoptera acutorostrata	Minke whale	1010	Monthly	
	Balaenoptera borealis	Sei whale	589	Monthly	
	Balaenoptera musculus	Blue whale*	7	Year-round	
	Balaenoptera physalus	Fin whale	1730	Monthly	
	Delphinus delphis	Common dolphin	803	Monthly	
	Eubalaena glacialis	North Atlantic right whale	1595	Monthly	
	Globicephala	Unidentified pilot whale	670	Yearly	Pilot whales
	Grampus griseus	Risso's dolphin	514	Monthly	
	Hyperoodon ampullatus	Northern bottlenose whale	3	Year-round	
	Kogia	Unidentified small sperm whale	3	Year-round	Kogia whales*
	Kogia sima	Dwarf sperm whale	1	Year-round	Kogia whales*
	Lagenorhynchus acutus	Atlantic white-sided dolphin	1677	Monthly	
	Lagenorhynchus albirostris	White-beaked dolphin	12	Year-round	
	Megaptera novaeangliae	Humpback whale	2700	Monthly	
	Mesoplodon	Unidentified beaked whale	82	Year-round	Beaked whales
	Mesoplodon bidens	Sowerby's beaked whale	8	Year-round	Beaked whales
	Mesoplodon densirostris	Blainville's beaked whale	2	Year-round	Beaked whales
	Mesoplodon mirus	True's beaked whale	2	Year-round	Beaked whales
	Orcinus orca	Killer whale*	4	Year-round	
	Phocoena phocoena	Harbor porpoise	2781	Monthly	
	Physeter	Sperm whale	247	Monthly	

	macrocephalus				
	Stenella attenuata	Pantropical spotted dolphin*	4	Year-round	
	Stenella coeruleoalba	Striped dolphin	84	Year-round	
	Stenella frontalis	Atlantic spotted dolphin*	7	Year-round	
	Stenella longirostris	Spinner dolphin*	1	Year-round	
	Tursiops truncatus	Bottlenose dolphin	477	Monthly	
	Ziphiidae	Unidentified beaked whale	2	Year-round	Beaked whales
	Ziphius cavirostris	Cuvier's beaked whale	21	Year-round	Beaked whales
Pinnipeds	Caniformia	Unidentified seal	909	Seasonal	Seals
	Halichoerus grypus	Gray seal	24	Seasonal	Seals
	Phoca vitulina	Harbor seal	250	Seasonal	Seals
Turtles	Caretta	Loggerhead turtle	470	TBD	TBD
	Chelonia mydas	Green turtle	3	TBD	TBD
	Dermochelys coriacea	Leatherback turtle	232	TBD	
	Lepidochelys kempii	Kemp's ridley turtle	59	TBD	TBD

*Rare species, but not absent from Northeast Region. MDAT has modeled this species, but can omit from delivered products if requested.

3.3 Marine mammal/Sea turtle habitat density model outputs

General description

The Duke MGEL team is leading the MDAT effort to provide quantitate information products (maps) on the distribution and abundance of marine mammals and sea turtles in the northeast region. MGEL has been working with the National Aeronautics and Space Administration (NASA), NOAA's Southwest Fisheries Science Center (SWFSC), NOAA's Cetacean & Sound Mapping Working Group, and the Navy to create the best available marine mammal habitat-based density (HD) models for the US East Coast. Continuing on that work for this NROC effort, MDAT is adding models for sea turtles. Models are created by applying distance sampling methods to visual line transect surveys and linking physiographic and oceanographic covariates (Table 3) via Generalized Additive Models (GAMs). Oceanographic covariates may be climatological (e.g. mean monthly sea surface temperature at the location of the sighting averaged over 30 years) or contemporaneous (daily sea surface temperature on the date of the sighting) – the better performing model is selected.

HD models predict density as animals per square kilometer (Figure 3). Ecologically similar species that have too few sightings to model individually are modeled as a group (e.g. beaked whales).

Table 3. Oceanographic covariates used in habitat density models. Not all variables are used in each model, the model selects the best predictor variables for each species.

Type	Predictor	Description
Physiographic	Depth	Downscaled from SRTM30-PLUS to 10km resolution
	Slope	Computed from SRTM30-PLUS
	DistToShore	Distance to shore, not including Bermuda
	DistTo125m, DistTo300m, DistTo1500m	Distance to isobaths that delineate various ecologically relevant geomorphic features
	DistToCanyon	Distance to submarine canyon
	DistToCanyonOrSeamount	Distance to submarine canyon or seamount
SST & Winds	SST	Taken from GHRSST CMC 2.0 L4 SST, interpolated up to 10 km resolution
	DistToFront	Distance to closest SST front detected in CMC SST using Canny edge detection operator; tested several alternative formulations
	WindSpeed	30-day running mean of NCDC 1/4° Blended Sea Winds, interpolated up to 10 km resolution; only used for calving right whales in the southeast
Currents	TKE, EKE	Total kinetic energy and eddy kinetic energy derived from AVISO 1/4° DT-MADT and MSLA geostrophic currents, interpolated up to 10 km resolution
	DistToEddy, DistToAEddy, DistToCEddy	Distance to ring of closest geostrophic eddy having any/anticyclonic/ cyclonic polarity, from Chelton et al. (2011) database; tested eddies at least 9 weeks old, at least 4 weeks old, and without a minimum age
Productivity	Chl1	GSM merged SeaWiFS/Aqua/MERIS/VIIRS 9km daily chl-a concentration, smoothed with 3D Gaussian smoother to reduce data loss to < 10%; tested two smoothing formulations
	VGPM	Behrenfeld et al. vertically generalized primary prod. model (VGPM) at 8-day, 9km resolution, trilinear-interpolated to daily resolution; also tested 45 and 90 day running cumulative sums
	PkPP, PkPB	Weekly zooplankton potential production and potential biomass from the SYPODYM ocean model
	EpiMnkPP, EpiMnkPB	Weekly epiplelagic micronekton potential production and potential biomass from the SYPODYM ocean model

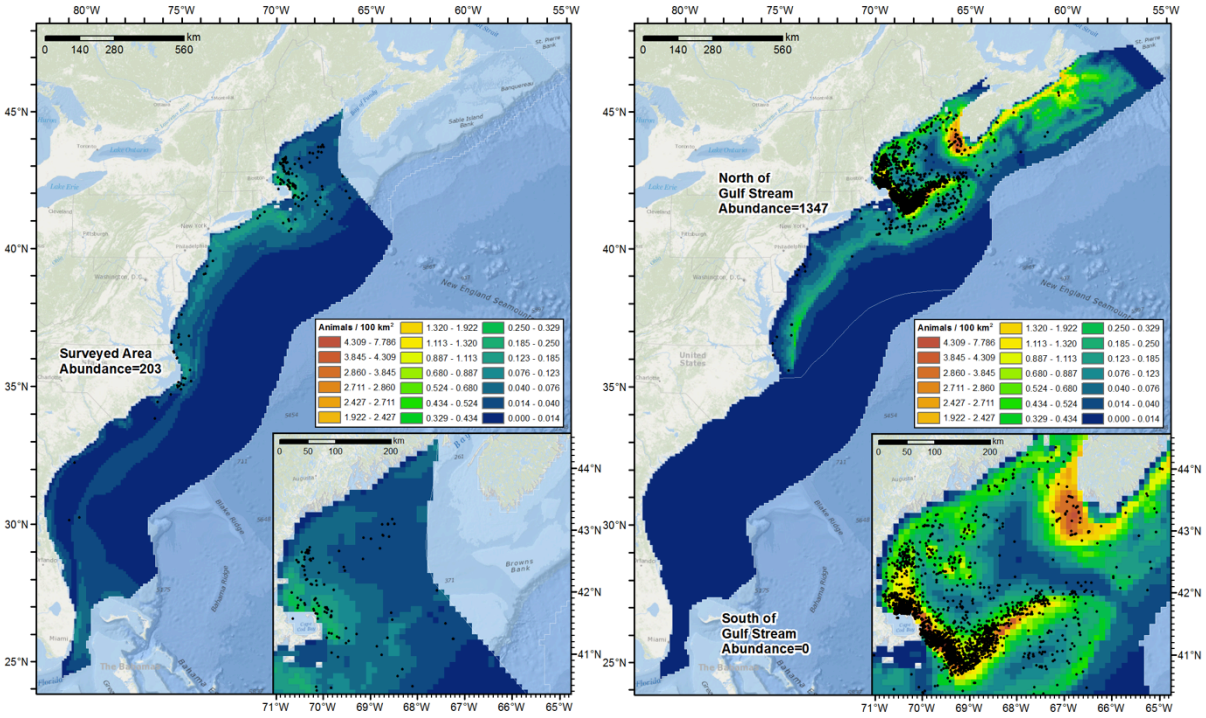

Figure 3. Example model output for humpback whales for winter (left: December, January, February and March) and summer (right: April, May, June, July, August, September, October, November). Sightings are shown as black dots. Species-specific seasons are determined through literature and patterns in the sightings data. Model output products created for the NROC effort will be clipped to the Northeast Region.

Spatial coverage, grid size, model gaps

Marine mammal and sea turtle models are being created for the entire US East Coast, and derived products for this NROC effort will be constrained to the Northeast spatial extent in Figure 1. Model output is a grid consisting of 10km^2 cells, which is a compromise between resolutions of oceanographic covariates, which range from 4km to 1/3°. Spatial gaps include: New York/New Jersey Harbor, Long Island Sound, all of the bays around Long Island, part of Block Island Sound, Narragansett Bay and nearby passages, part of Buzzard's Bay, part of Massachusetts Bay, and various bays along Maine and Canada.

Temporal coverage, assessment windows, model gaps

Data sources range from 1992 – 2014. Model output will be on a seasonal or monthly basis when the data support that resolution, otherwise more coarse temporal predictions will be provided (Table 2). Species-specific seasons are based on patterns in the sightings and reports in the literature.

Characterization(s) of model uncertainty

Several measures of model uncertainty will be provided for the habitat-based density models (Figure 3). The percentile maps reflect the statistical uncertainty of the GAM that is predicting density from environmental predictors. The uncertainty at a given location relates mainly to how well the environmental conditions that occurred there were surveyed, and how variable conditions are throughout the year.

1. 5th percentile – This measure indicates that the density of animals predicted by the model exceeds what is shown on the map 95% of the time, meaning high densities are reliably predicted as high.
2. 95th percentiles – On the 95th percentile map, the density of animals predicted by the model exceeds what is shown on the map only 5% of the time.
3. Standard error – Standard error relates the deviation in the error of the model's predicted mean animal density, and can give an indication of correctness for the predictions.
4. Coefficient of variation (CV) – The CV is a measure of the variability in predicted animal density with respect to the mean, and helps inform users about the magnitude of variation in model predictions. Values greater than one indicate that the model deviation in that area is greater than the mean predicted density of animals.

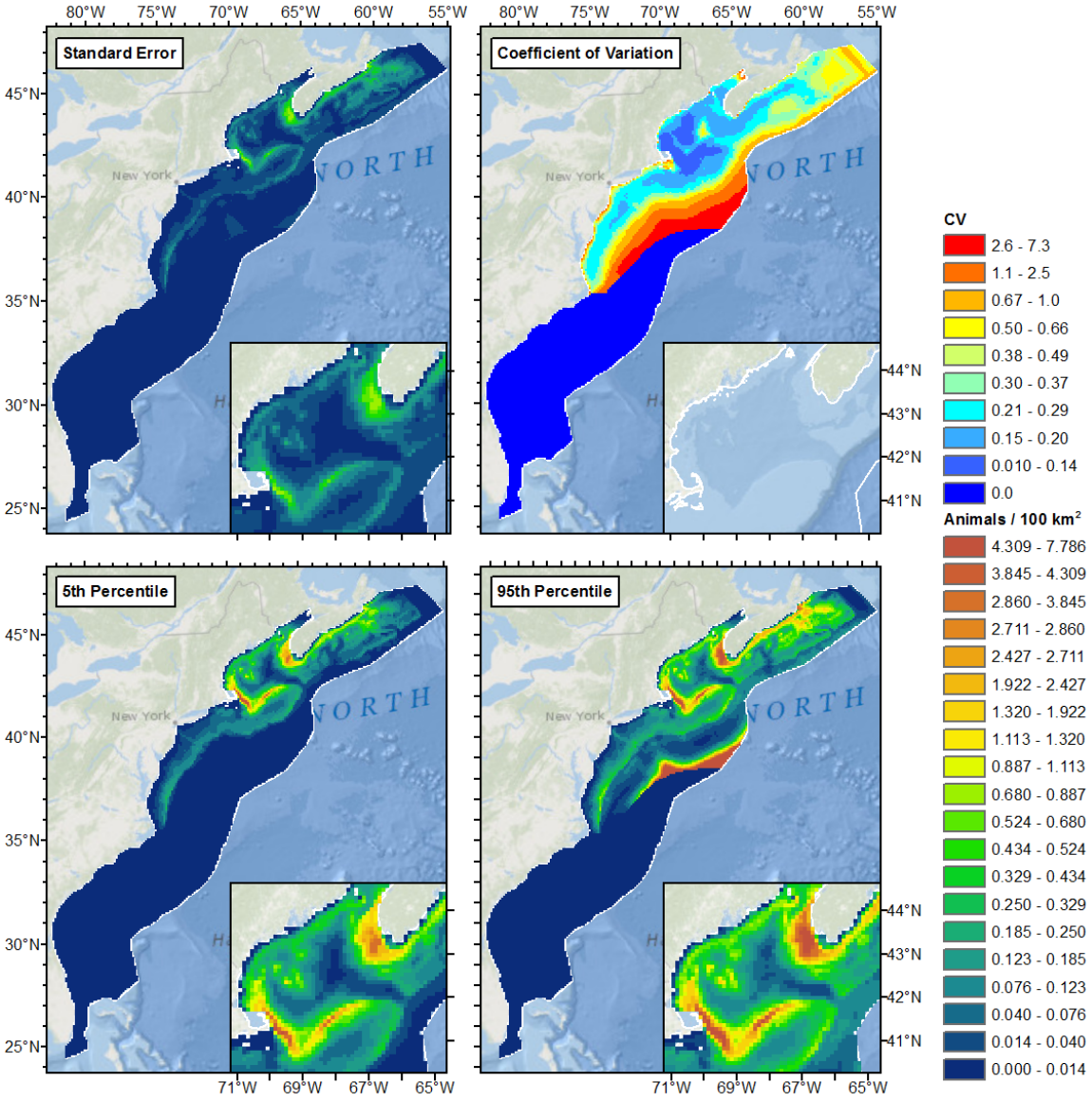

Figure 3. Example map output for model uncertainty measures.

3.4 Other Marine mammal/Sea turtle data products – fill spatial, temporal, other data gaps

Marine mammal/Sea turtle Sightings Per Unit Effort map options

Data source(s)

While the habitat-based density models show predicted absolute density of animals in modeled areas, the Sightings Per Unit Effort (SPUE) maps show relative abundance in areas covered by observation data (Figure 4). The same data sources in Table 1 can be used to create SPUE maps for each species or species group listed in Table 2. SPUE maps are based on aerial effort or shipboard effort, and if line transect data is used as the basis, these SPUE maps would be based on data that is corrected for species- and survey-specific detectability rates. The North Atlantic Right Whale Consortium (NARWC) database of marine mammal and sea turtle sightings could also be used as a source for SPUE products. MDAT currently has the raw sightings data from the NARWC, which would need to be effort-corrected to produce meaningful SPUE products. Additionally, there are potentially data in the MDAT database (Table 1) that don't exist in the NARWC database. Creating products with both sources is an option to be discussed with the working group, with the understanding of effort required and resources available.

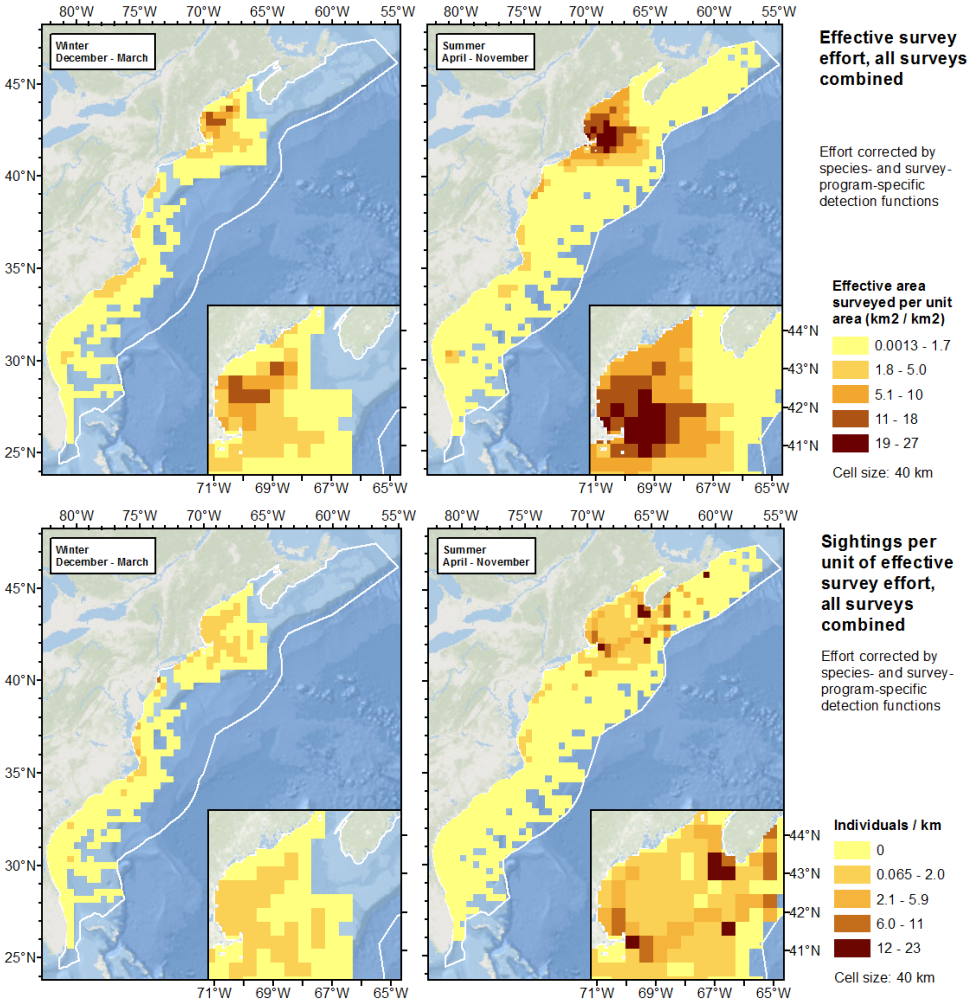

Figure 4. Example Sightings per Unit Effort (SPUE) maps for humpback whales along the US East Coast.

Spatial coverage
SPUE maps will use the same areal extent for the Northeast region shown in Figure 1.

Resolution
SPUE maps are at a planned resolution of 40 km^2 grids, to minimize gaps and noise. If time permits, this resolution could be decreased based on feedback from the expert working group and NROC, with understanding of the tradeoffs (more spatial gaps and more noise except where intensive surveying was done). Previous SPUE products for portions of the Northeast region have been produced at various resolutions, including as low as a 3-minute (~6 km) grid for Cape Cod Bay (Nichols et al. 2008).

Maps of raw Marine mammal/Sea turtle observations

Data source(s)
In addition to the sources in Table 1, raw sightings maps will draw from the NARWC database as appropriate.

Spatial coverage
Observation and effort maps will use the same spatial extent for the Northeast region shown in Figure 1.

Mapping approach
Maps will be created that show survey effort and species observation points (e.g. Figure 4).

3.5 Synthetic data products for Marine mammals/Sea turtles

Guilds / Groupings

Grouping of species for synthetic data products could be established following discussions within the working group. The groups could follow regulatory frameworks or ecological factors.

Diversity

Synthetic data products such as diversity and species richness could be derived following discussion within this working group, between the two other working groups and with NROC. Such derived products would cover the same extent and spatial resolution as the model output described above.

Other
Based on guidance from NROC and working group members, additional mapping products for selected species could include ecological hot-spot, core habitat, migratory corridor and other potentially important habitat areas, created from the distribution and abundance products. Overlays with offshore energy development areas, state planning areas and other regulatory frameworks are other potential products that could be useful to regional ocean planners.

3.6 Literature Cited

Behrenfeld MJ, Falkowski PG (1997) Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and Oceanography Volume 42: 1-20.

Chelton DB, Schlax MG, Samelson RM (2011) Global observations of nonlinear mesoscale eddies. Progress in Oceanography Volume 91(2): 167-216.

Nichols, OC, Kenney RD, Brown MW (2008) Spatial and temporal distribution of North Atlantic Right Whales in Cape Cod Bay, and implications for management. Fishery Bulletin 108: 270-280.