OCEAN PLANNING IN THE NORTHEAST

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

Avian Species

Brian Kinlan[1], Earvin Balderama[2], Arliss Winship[1]

[1]NOAA Centers for Coastal Ocean Science
[2] Loyola 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).

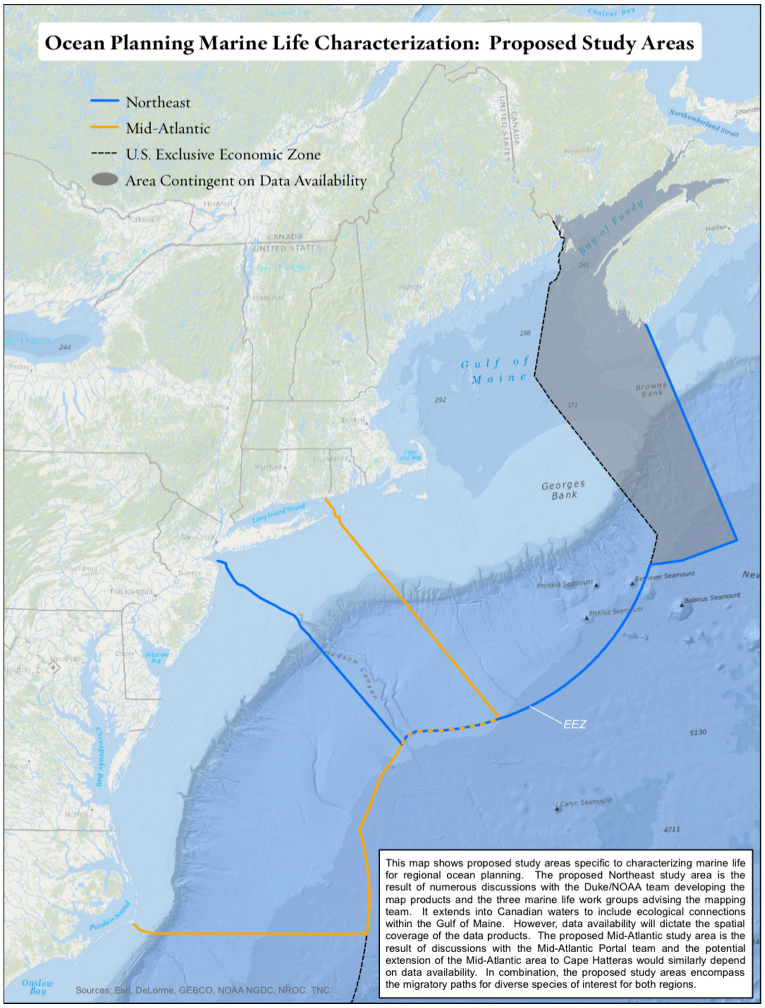
1 Introduction

The National Ocean Policy, established by Presidential Executive Order in 2010, called for the formation of nine Regional Planning Bodies (RPBs) to better manage the nation's oceans and coasts. The Northeast RPB is the first in the nation to begin this planning process, and NOAA's National Centers for Coastal Ocean Science (NCCOS) is supporting the marine life assessment component of that process in partnership with Duke University and NOAA Fisheries (the Marine life Data Analysis Team [MDAT]). NCCOS is leading the MDAT Avian Working Group, which is coordinating a comprehensive synthesis of models and data on marine and coastal birds to develop spatial analyses and map products for use in the NE RPB planning process. This work leverages NCCOS's current project funded by the Bureau of Ocean Energy Management (BOEM) to produce long-term average predictive maps of marine bird distribution and abundance from large databases of at-sea transect survey and environmental data in the US Atlantic. These models are complemented by a collaboration with Loyola University through which predictive maps of persistence and probability of very large aggregations of marine birds are being developed, and other projects in the NE Region collecting and analyzing data on tidal, marsh, and shorebirds (e.g., the SHARP project http://www.tidalmarshbirds.org/).

This document describes the final analysis plan for the MDAT Avian Working Group, comprising the geographic and taxonomic scope of analyses, an overview the source data and analytical methods, and anticipated map products that will be provided to the Northeast Regional Ocean Council (NROC) and Northeast RPB in late Summer 2015 for distribution on public data portals and use by the RPB to inform next steps in development of the Northeast Regional Ocean Plan. We are grateful to the many experts from federal, state, NGO, and academic institutions who have contributed their time over the past nine months to participate in the Avian Working Group through webinars and email feedback. This analysis plan reflects a balanced approach taking into account expert feedback through the working group, input from the NE RPB through NROC participation in the working group, and the scope of the MDAT's mission.

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.



Ocean Planning Marine Life Characterization: Proposed Study Areas

This map shows proposed study areas specific to characterizing marine life for regional ocean planning. The proposed Northeast study area is the result of numerous discussions with the Duke/NOAA team developing the map products and the three marine life work groups advising the mapping team. It extends into Canadian waters to include ecological connections within the Gulf of Maine. However, data availability will dictate the spatial coverage of the data products. The proposed Mid-Atlantic study area is the result of discussions with the Mid-Atlantic Portal team and the potential extension of the Mid-Atlantic area to Cape Hatteras would similarly depend on data availability. In combination, the proposed study areas encompass the migratory paths for diverse species of interest for both regions.

Sources: Esri, DeLorme, GEBCO, NOAA NGDC, NROC, TNC

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

3 Marine birds

3.1 Source data for marine birds

- Marine bird survey data from the United States Geological Survey (USGS) and United States Fish and Wildlife Service (USFWS) ‘Compendium of Avian Occurrence Information for the Continental Shelf waters along the Atlantic Coast of the U.S.’ (described in this technical memorandum: www.data.boem.gov/PI/PDFImages/ESPIS/5/5193.pdf)
- We will use the 1 August 2014 version of all science-quality at-sea transect data from the Compendium, standardized into 15-minute, 10 knot equivalent transect segments
- NCCOS modeling will analyze 75 datasets (Table 1)
- Loyola University modeling will analyze datasets with data collected in the time range from July 1998 to April 2014. (The time range of the Loyola model is restricted by availability of consistent monthly satellite data on chlorophyll and sea surface temperature).

Table 1. Datasets to be analyzed. The number of standardized transect segments within the study area is indicated by *n*. Datasets with an asterisk are not publicly available, but have been or are expected to be made available to us for use in modeling under a restricted usage agreement with the data owner or manager.

Code	Platform	Dates	Geographic range	n
AMAPPS_FWS_Aerial_Preliminary_Summer2010	aerial	Aug 2010	NC to FL	1863
AMAPPS_FWS_Aerial_Winter2010-2011	aerial	Dec 2010 – Jan 2011	NJ to NC	914
AMAPPS_FWS_Aerial_Summer2011	aerial	Jul-Aug 2011	entire coast	5177
AMAPPS_FWS_Aerial_Spring2012	aerial	Mar 2012	entire coast	5270
AMAPPS_FWS_Aerial_Fall2012	aerial	Sep-Oct 2012	entire coast	5157
AMAPPS_NOAA/NMFS_NEFSCBoat2011	boat	Jun-Jul 2011	offshore MA to NC	1274
AMAPPS_NOAA/NMFS_NEFSCBoat2013	boat	Jul-Aug 2013	offshore MA to NC	1318
AMAPPS_NOAA/NMFS_NEFSCBoat2014	boat	Mar-Apr 2014	offshore MA to NC	859
AMAPPS_NOAA/NMFS_SEFSCBoat2011	boat	Jun-Jul 2011	offshore MD to FL	822
AMAPPS_NOAA/NMFS_SEFSCBoat2013	boat	Jul-Sep 2013	offshore MD to GA	813
BarHarborWW05	boat	Jun – Oct 2005	ME	911
BarHarborWW06	boat	Jun – Oct 2006	ME	1022
CapeHatteras0405	boat	Aug 2004 – Feb 2005	NC	276
CapeWindAerial*	aerial	Mar 2002 – Feb 2004	MA	4035
CapeWindBoat*	boat	Apr 2002 – Sep 2003	MA	252
CDASMidAtlantic	aerial	Dec 2001 – Mar 2003	NJ to VA	1402
CSAP	boat	Apr 1980 – Oct 1988	entire coast	26271
DOEBRIBoatApril2012*	boat	Apr 2012	DE to VA	142
DOEBRIBoatJune2012*	boat	Jun 2012	DE to VA	143
DOEBRIBoatAug2012*	boat	Aug 2012	DE to VA	142
DOEBRIBoatSep2012*	boat	Sep 2012	DE to VA	144
DOEBRIBoatNov2012*	boat	Nov 2012	DE to VA	142
DOEBRIBoatDec2012*	boat	Dec 2012 – Jan 2013	DE to VA	139
DOEBRIBoatJan2013*	boat	Jan–Feb 2013	DE to VA	143
DOEBRIBoatMar2013*	boat	Mar 2013	DE to VA	145
DOEBRIBoatMay2013*	boat	May 2013	DE to VA	147
DOEBRIBoatJun2013*	boat	Jun 2013	DE to VA	146
DOEBRIBoatAug2013*	boat	Jul–Aug 2013	DE to VA	145
DOEBRIBoatSep2013*	boat	Sep 2013	DE to VA	148
DOEBRIBoatOct2013*	boat	Oct 2013	DE to VA	147
DOEBRIBoatDec2013*	boat	Dec 2013	DE to VA	147

DOEBRIBoatJan2014*	boat	Jan–Feb 2014	DE to VA	143
DOEBRIBoatApr2014*	boat	Apr 2014	DE to VA	140
EcoMonMay07	boat	May–Jun 2007	ME to NC	435
EcoMonAug08	boat	Aug 2008	ME to NC	411
EcoMonJan09	boat	Jan–Feb 2009	ME to NC	341
EcoMonMay09	boat	May–Jun 2009	ME to NC	543
EcoMonAug09	boat	Aug 2009	ME to NC	395
EcoMonNov09	boat	Nov 2009	ME to NC	379
EcoMonFeb10	boat	Feb 2010	ME to VA (not northern Gulf of ME)	292
EcoMonMay10	boat	May–Jun 2010	ME to NC	550
EcoMonAug10	boat	Aug–Sep 2010	Gulf of ME and offshore	427
EcoMonNov10	boat	Nov 2010	ME to NC	356
EcoMonNov2011	boat	Oct–Nov 2011	ME to NC	391
EcoMonFeb2012	boat	Feb 2012	ME to NC	472
EcoMonJun2012	boat	May–Jun 2012	MA to VA	389
EcoMonAug2012	boat	Aug 2012	ME to NC	560
EcoMonOct2012	boat	Oct–Nov 2012	ME to MD	428
FWSAtlanticWinterSeaduck2008	aerial	Feb 2008 – Feb 2011	entire coast	14377
FWS_MidAtlanticDetection_Spring2012	aerial	Mar 2012	VA	456
FWS_SouthernBLSC_Winter2012	aerial	Feb 2012	SC to GA	1582
GeorgiaPelagic	boat	Nov 1982 – Jun 1985	SC to FL (also Gulf of ME and offshore)	2187
HatterasEddyCruise2004	boat	Aug 2004	NC	93
HerringAcoustic06	boat	Sep 2006	Gulf of ME	243
HerringAcoustic07	boat	Oct 2007	Gulf of ME	283
HerringAcoustic08	boat	Sep–Oct 2008	Gulf of ME	710
HerringAcoustic09Leg1	boat	Sep 2009	Gulf of ME	109
HerringAcoustic09Leg2	boat	Sep–Oct 2009	Gulf of ME	245
HerringAcoustic09Leg3	boat	Oct 2009	Gulf of ME	227
HerringAcoustic2010	boat	Sep–Oct 2010	Gulf of ME	482
HerringAcoustic2011	boat	Sep–Oct 2011	Gulf of ME	690
MassAudNanAerial	aerial	Aug 2002 – Mar 2006	MA	4131
NewEnglandSeamount06	boat	Oct 2006 – Jun 2007	east of Gulf of ME	66
NJDEP2009	aerial and boat	Jan 2008 – Dec 2009	NJ	4446
NOAA/NMFS_NEFSCBoat2004	boat	Jun–Aug 2004	offshore MA to MD	1017
NOAA/NMFS_NEFSCBoat2007	boat	Aug 2007	Gulf of ME	516
NOAAMBO7880	boat	Jan 1978 – Nov 1979	mostly ME to NC, but also GA	6979

			and FL	
PlattsBankAerial	aerial	Jul 2005	Gulf of ME	732
RISAMPAerial	aerial	Dec 2009 – Aug 2010	RI	2158
RISAMPBoat	boat	Jul 2009 – Aug 2010	RI	653
SEFSC1992	boat	Jan–Feb 1992	NC to FL	674
SEFSC1998	boat	Jul–Aug 1998	MD to FL	1146
SEFSC1999	boat	Aug–Sep 1999	NJ to FL	1058
WHOIJuly2010*	boat	Jul 2010	offshore NY Bight	71
WHOISept2010*	boat	Sep 2010	Gulf of ME	74

3.2 Avian species and groupings

- NCCOS will attempt to develop models for all species-season combinations for which there are at least 100 transect segments with a sighting of that species (Table 2); NCCOS will also consider modeling species-seasons combinations when there are at least 50 transect segments with a sighting. It is possible that 50-100 observations will be insufficient to develop robust models for some species/season combinations with highly skewed abundance distributions (e.g., Common eider). These will be noted and handled as "non-modeled high priority species"; non-modeled seasons will not be included in annual averages and annual averages will assume zero abundance in non-modeled seasons.
- Loyola University will develop models for the "Priority 1" species listed in the table below, and consider additional Priority 2, 3, or 4 species on request from the Avian Working Group, NROC, and NE RPB, subject to resource limitations and final determination by the MDAT team.

Table 2. Species sample sizes and priority. Cells without shading indicate species-season combinations for which models will be attempted by NCCOS. Cells shaded in light grey indicate species-season combinations for which models *may* be attempted by NCCOS. Cells shaded in dark grey indicate species-season combinations that will *not* be modeled by NCCOS.

Species	Number of standardized transect segments with sightings				Priority
	Spring	Summer	Fall	Winter	
Razorbill	720	78	170	1559	1
Black scoter	423	16	356	1163	1
White-winged scoter	415	5	550	1332	1
Common eider	893	159	537	2211	1
Red-throated loon	1699	11	387	1902	1
Great shearwater	586	6011	6176	134	1
Audubon's shearwater	129	876	286	169	1
Red-necked phalarope	132	167	156	14	1
Least tern	27	121	37	0	1
Roseate tern	56	195	74	3	1
Common tern	488	1538	683	4	1
Northern gannet	5667	1187	4002	6414	1
Red phalarope	461	214	286	44	1

Black guillemot	7	93	7	34	2
Atlantic puffin	209	246	91	249	2
Long-tailed duck	1152	1	485	3214	2
Surf scoter	745	8	761	1746	2
Common loon	2367	182	1185	3215	2
Leach's storm-petrel	223	2140	452	1	2
Brown pelican	66	127	87	76	2
Horned grebe	21	0	13	94	2
Cory's shearwater	106	2925	1547	1	2
Black-capped petrel	158	356	92	83	2
Arctic tern	44	154	44	0	2
Dovekie	260	49	404	962	3
Band-rumped storm-petrel	14	266	10	0	3
Bonaparte's gull	397	20	280	981	3
Laughing gull	711	1602	1560	114	3
Black-legged kittiwake	621	24	2083	3706	3
Sooty shearwater	790	1542	104	3	3
Manx shearwater	100	309	264	16	3
Royal tern	269	283	279	11	3
Common murre	90	22	5	160	4
Red-breasted merganser	73	0	26	121	4
Wilson's storm-petrel	1650	8392	1348	10	4
Herring gull	5721	2941	7439	4986	4
Ring-billed gull	181	46	312	704	4
Great black-backed gull	3423	3186	5390	3655	4
Double-crested cormorant	145	187	206	162	4
Northern fulmar	2244	737	1823	1809	4
South polar skua	22	74	121	0	4
Parasitic jaeger	47	76	177	12	4
Pomarine jaeger	110	144	709	21	4
Great skua	16	27	173	26	4
Bridled tern	33	101	63	3	4
Sooty tern	60	118	16	0	4

Other species

Co-I Kinlan is also engaged with working groups and collaborators who are collating marine bird telemetry and colony data for the region and integrating shore-based data (e.g., USFWS Colonial Waterbird Database, Saltmarsh Habitat and Avian Research Project [SHARP], state Natural Heritage Programs). To the extent possible, we will complement our model-based analyses with maps of spatial data and model outputs from these other projects. For example, SHARP is developing models for several coastal and saltmarsh species including clapper rail, saltmarsh (sharp-tailed) sparrow, Nelson’s sparrow, and seaside sparrow. We will also coordinate with the NOAA updates to the coastal Environmental Sensitivity Index (ESI) from North Carolina to Maine, which will include information on shore, marsh, and other near-coast bird species not covered by modeling efforts. Coordination with these efforts will primarily be managed by MDAT staff at Duke and NROC staff.

The exact map products that will be available from these collaborative efforts have not yet been determined, and will depend on available resources. At a minimum, we will provide NROC and the NE RPB with information on the other projects that exist, the species analyzed by those projects, and contact information for those project PI's. If time permits, the Duke MDAT team will produce map products from data provided by those collaborative products in the same geospatial framework as the rest of the MDAT analyses.

See Section 3.5, below, for more information.

3.3 NCCOS model outputs

Modeling framework

NCCOS has been leading marine bird modeling work for marine spatial planning in the Northeast US since 2010, in collaboration with partners at BOEM, USGS, USFWS, DOE, NOAA/NMFS, New York State, NC-State, CUNY, Biodiversity Research Institute, and other regional institutions (Menza et al. 2012, Kinlan et al. 2012b, Kinlan et al. 2012a, Zipkin et al. 2014). Building on this work led by Co-I Kinlan, we are now expanding the scope of our marine bird modeling to the entire U.S. EEZ from Florida to Maine. Models are being developed using a combination of at-sea marine bird survey data extracted from the USFWS/USGS Avian Compendium database, and marine environmental data records including fronts, primary productivity, and ocean currents.

Models of occurrence and abundance will be integrated to develop a comprehensive suite of high-resolution map products, with associated accuracy assessments, to aid in spatial planning and environmental assessment. These models incorporate virtually all known science-quality at-sea seabird surveys from 1978-2014 (Table 1), including all AMAPPS and USFWS aerial and boat surveys, BRI's Mid-Atlantic Baseline surveys (aerial Hi-Def and boat), and recent surveys conducted by states, BOEM, and wind energy companies to inform energy siting off Rhode Island, Massachusetts, Maine, and elsewhere in the NE. Coverage in the Northeast is excellent (Figure 2), so we expect models to perform well in this region—though uncertainty maps and accuracy assessments will also be a key element of our work.

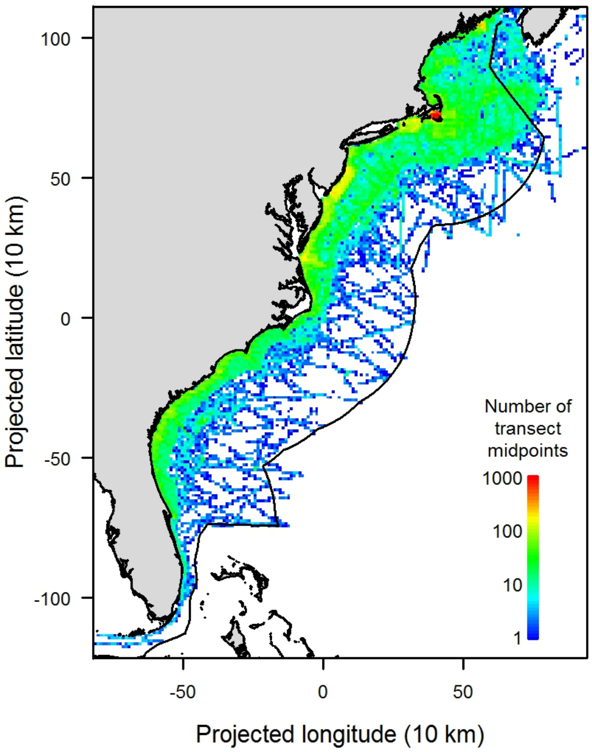


Figure 2. Survey effort coverage for the model effort.

Co-I Kinlan will work with MDAT analytical staff to extract, develop, enhance, and customize results from this larger modeling effort to create the best possible high-resolution (2km) maps of marine bird distribution and abundance in the NE region, and other spatial products specifically designed to answer management and planning questions refined in consultation with expert working groups. We will also produce maps of uncertainty and conduct accuracy assessments to test model predictive skill and accuracy. We will deliver a complete set of spatial products and accuracy assessments for important species of seabirds reflected in at-sea surveys in the region.

Specific features of the NCCOS modeling approach include:

- NCCOS will be employing a statistical modeling framework that relates occurrence and abundance to environmental predictor variables (Table 3)
- Seasonal climatologies of spatial environmental predictors will be used (i.e., a climatological habitat modeling approach)
- A boosted generalized additive modeling framework will be used that accounts for the large number of zero data (zero inflation) and the overdispersed nature of marine bird count data

Table 3. Environmental predictor variables for NCCOS model.

Variable	Type	Seasonal
chlorophyll-a	spatial	yes
turbidity	spatial	yes
upwelling index	spatial	yes
sea surface temperature	spatial	yes

sea surface temperature SD	spatial	yes
sea surface temperature front probability	spatial	yes
sea surface height	spatial	yes
sea surface height SD	spatial	yes
probability of cyclonic eddy ring	spatial	yes
probability of anticyclonic eddy ring	spatial	yes
water current (u direction)	spatial	yes
water current (v direction)	spatial	yes
water current divergence	spatial	yes
water current vorticity	spatial	yes
wind stress (u direction)	spatial	yes
wind stress (v direction)	spatial	yes
wind divergence	spatial	yes
depth	spatial	no
slope (1.5 and 10 km resolution)	spatial	no
slope of slope (10 km resolution)	spatial	no
planform curvature (10 km resolution)	spatial	no
profile curvature (10 km resolution)	spatial	no
distance to shelf break (200 m isobath)	spatial	no
distance to land	spatial	no
longitude (projected)	spatial	no
latitude (projected)	spatial	no
year	temporal	n/a
day of year	temporal	n/a
Monthly North Atlantic Oscillation (NAO) index (current and 1-year lag)	temporal	n/a
Monthly Multivariate El Nino-Southern Oscillation index (MEI) (current and 1-year lag)	temporal	n/a
Monthly Trans-Nino Index (TNI) (current and 1-year lag)	temporal	n/a
Monthly Atlantic Multidecadal Oscillation (AMO) index (current and 1-year lag)	temporal	n/a

Spatial coverage and grid size

- The NCCOS study area will cover the region indicated in Figure 1 excluding the Bay of Fundy, Long Island Sound, and inshore, nearshore, and estuarine areas. Some additional areas where environmental predictors and/or at-sea bird survey transect data are lacking are not excluded from the study area per se, but are unlikely to have valid predictions. Generally speaking, with the exception of estuaries/embayments that have been excluded and some areas very far offshore where there are survey data gaps (see Fig. 2), predictions will be made through most of the domain from approximately 1-2km offshore to the US EEZ boundary.
- Compendium survey data have a reasonable coverage of the entire study area, although there are more data nearer to the coast and over the shelf than further offshore
- NCCOS will predict species occurrence and abundance at a 2-km spatial resolution
- Model predictions may be absent within 0-2km of the coast due to the 2km model resolution and problems with obtaining reliable remote sensing and ocean model predictor data in the shore zone.

Temporal coverage

- NCCOS will model survey data that span January 1978 through April 2014
- The majority of the survey data are from the late 1970s, 1980s, 2000s, and 2010s with few data from the 1990s
- NCCOS models will predict 'long-term' spatial distributions during the timespan of the data while accounting for temporal changes in overall occurrence and abundance (e.g., long-term average, long-term median, etc.)
- Some temporal effects are included in the models (see Table 3), but these temporal effects are non-spatial. They can be used to diagnose region-wise patterns of daily variation within seasons, inter-annual effects of ocean climate changes, and anomalous years. These temporal effects will not be summarized in detail as part of MDAT products, but NCCOS is in the process of producing a detailed report on their larger modeling efforts (Florida to Maine) that will provide detailed information on these temporal effects. This report is expected to be available to NROC and the RPB on request by July 2015.
- For seasonal models, seasons are defined as:
- Winter: December 1 to February 28/29
- Spring: March 1 to May 31
- Summer: June 1 to August 31
- Fall: September 1 to November 30

Anticipated model products

The models will produce a wide array of raw outputs, but based on discussions with the Avian Working Group we have targeted the products listed in Table 5, below. These will be further synthesized as described in section 3.6.

Characterization of model uncertainty

A bootstrap (data resampling and repeated model re-fitting) approach will be used to characterize uncertainty in model predictions. Uncertainty products are described in Table 6, below.

3.4 Loyola model outputs

Through the sub-award to MDAT Co-Investigator Balderama (Loyola University Chicago), we will also incorporate model products specifically tailored to look at extreme abundances, which is especially important for assessing potential risks of offshore activities to seaducks and other highly aggregative species. We will develop products that utilize results of a recent research project under a North Atlantic Landscape Conservation Cooperative grant (NALCC 2011, Mapping Marine Birds NW Atlantic: Phase 1, informally known as the "Best Darn Bird Map" project – PI Beth Gardner, NC State, Balderama's former Post-doc advisor). The statistical models that were developed for this project used a Bayesian hierarchical approach to properly account for potential bias in offshore survey efforts, and to examine spatial extremes of count distributions (i.e., the large aggregations often reported in sea bird surveys and avoided in the analysis of such data). The main results of this modeling effort were demonstrated with monthly distribution maps of seabirds, characterizing areas of potential exposure and aggregation for individual species. Kinlan and Balderama have previously collaborated on this project and are well positioned to integrate these model products with the NCCOS Atlantic Coast model products. By trading off spatial resolution (4km grid cells vs. 2km NCCOOS resolution), and considering only SST and chlorophyll as dynamic predictors, the Loyola model gains temporal resolution (predictions are made monthly), allowing us to assess persistence of extreme aggregations. Loyal models will also predict in embayments where survey data are available. However, predictions will not be produced in offshore areas beyond the 400m isobath.

Co-I Balderama will expand previous modeling efforts to cover the geographic extent of the proposed NE and Mid-Atlantic study area, although the Bay of Fundy and areas where ocean depth exceeds 400m will be excluded due to lack of sufficient data for temporally resolved models. The latest data sources will also be incorporated which will expand temporal coverage to 1998-2014 (compared to Balderama and Gardner's previous modeling efforts which used a 2002-2010 time period, a previous version of the Compendium data, and older single-sensor SST and Chlorophyll products).

Specific features of the Loyola modeling approach include:

- A double-hurdle model to account for both excessive zero-inflation and extreme overdispersion commonly seen in marine bird count data
- Environmental predictors, spatial and temporal random effects relate to model parameters through a hierarchical regression framework
- Spatial autocorrelation is modeled by a conditional autoregressive process.
- A Bayesian MCMC approach for the estimation of model parameters

Table 4. Predictor variables for Loyola model.

Variable	Type	Monthly
chlorophyll-a	spatial	yes
sea surface temperature	spatial	yes
depth	spatial	no
distance to land	spatial	no
longitude (projected)	spatial	no
latitude (projected)	spatial	no
month of year (sine transformed)	temporal	n/a
month of year (cosine transformed)	temporal	n/a

Spatial coverage, grid size

- 4km grid size; co-registered with the 2km NCCOS grid
- Spatial exclusions include: Northern Bay of Fundy, inshore (<4km from land and/or not where bird at-sea transect survey data are absent in the Compendium), nearshore (<4km and/or not where bird at-sea transect survey data are absent in the Compendium). Estuarine areas and embayments lacking bird at-sea transect survey data will be excluded.
- Grid cells where water depth is >400m will be excluded

Temporal coverage

July 1998-April 2014

Monthly resolution; however, standard map products will be summarized annually (see notes in Table 5).

Anticipated model products

The models will produce a wide array of raw outputs, but based on discussions with the Avian Working Group we have targeted the products listed in Table 5, below. These will be further synthesized as described in section 3.6.

Table 5. Anticipated products from Avian MDAT analyses.

Seabird specialized products	Produced by	Time scales for maps	# of maps per species
Long-term average or median relative occurrence probability	NCCOS	Seasonal and annual	5
Long-term average or median abundance	NCCOS	Seasonal and annual	5
Probability of extreme aggregations[a]	Loyola	Annual[b]	1[b]
Persistent aggregations[c]	Loyola	Annual[d]	1[d]
Maps of shore, marsh, and other near coast species not covered by models[e]	SHARP, NOAA OR&R	Seasonal and annual	5
Gridded maps of standardized survey effort/data richness	Duke	Seasonal and annual	5
Available information on non-modeled high priority species[f]	Duke	Seasonal and/or annual	1 to 5

[a] Threshold maps (threshold determined from 90th percentile of observed count per transect segment in region). Probability of exceeding threshold in at least one month of the year.

[b] Monthly maps of probabilities of exceeding the 90th percentile threshold will be generated in order to calculate the annual maps. However, we do not plan to provide the monthly maps as a standard product unless requested by RPB.

[c] Peak frequency (considering all months of the year) of >50% chance of exceeding 90th percentile, based on threshold exceedance probability maps calculated for every month in every year of the time series.

[d] Individual MM/YYYY threshold exceedance probability maps will be generated as an intermediate step toward calculating the annual persistent aggregation map, but will not be provided as standard products unless requested by the RPB.

[e] Collaborations with SHARP and ESI. SHARP collaboration (PI: Chris Elphick) will be directly managed by Emily Shumchenia and Duke Staff without direct NCCOS involvement. ESI collaboration will be managed by Emily Shumchenia and Duke Staff in coordination with Dan Dorfman (NCCOS) and NOAA's Office of Response and Restoration.

[f] See Section 3.5, below. These products are contingent on data and resource availability. Unrestricted raw data, and restricted raw data for which appropriate permissions can be obtained from data originators, will be provided by NCCOS to Duke from the August 1, 2014 copy of the Avian Compendium database. Duke Staff will coordinate with Emily Shumchenia to produce appropriate maps of raw transect count data for non-modeled high priority species.

Characterization of model uncertainty

See Table 6, below.

Table 6. Model uncertainty map products from Avian MDAT analyses.

Uncertainty & confidence products	Produced by	Time scales for maps	# of maps per species
95th – 5th percentile credible interval[a] – probability	Loyola	Annual	1
95th – 5th percentile range[b] – occurrence, abundance	NCCOS	Seasonal and annual	10
Bootstrap Coefficient of Variation (CV)[c] – occurrence, abundance	NCCOS	Seasonal and annual	10
Raw Data Locations and Survey Effort Density[d]	Duke	Seasonal and annual	5

[a] From posterior model estimate for each threshold map; summarized annually. Integrated measure of observation, process, and model error.

[b] From model fit bootstrap procedure. Reflects variability around the long-term average unexplained by model, including both model uncertainty and inherent variability in the occurrence and abundance of birds at a given location over time. Integrated measure of observation, process, and model error.

[c] From model fit bootstrap procedure. This measure of uncertainty, equal to the bootstrap mean divided by the bootstrap standard deviation at each pixel, identified places where model predictions are less consistent over bootstrap runs, i.e. where the model predictions themselves are less certain (as opposed to inherent temporal variability in the occurrence or abundance of birds). Focal measure of model uncertainty.

[d] In general, more completely and intensely sampled areas are likely to yield higher confidence predictions.

3.5 Other Avian data products – fill spatial, temporal, other data gaps

As time and resources allow, the MDAT team will also attempt to provide the following for key species of interest not fully covered by modeling efforts:

Maps of nearshore Avian observations

- Direct mapping of nearshore (0-3km from shore) observations from the Compendium; potentially including major estuaries/embayments not covered by the models
- Direct mapping of other high priority non-modeled species
- Saltmarsh Habitat & Avian Research Program (SHARP)
- Environmental Sensitivity Index (ESI) – distribution and abundance geospatial data for Long Island Sound coastal birds; additional regions as resources permit

3.6 Synthetic data products for marine birds

Syntheses of model outputs across groups will focus on the NCCOS model outputs, and will follow the methods described and illustrated in Kinlan et al. (2012).

Total diversity (H') index

To develop a species diversity index, the Shannon (H') diversity index will be calculated for each model grid cell using predicted mean or median relative abundances of species occurring there and reported in map form, similar to that shown in Kinlan et al. (2012) for the New York Bight.

Species richness index (N)

To develop a species richness index, a threshold relative occurrence probability (e.g., 0.001) will be selected below which a given bird species is considered to be generally absent from a model grid cell. The total number of modeled species in a given season and/or annually that exceed this threshold will be summed and reported in map form, similar to that shown in Kinlan et al. (2012) for the New York Bight.

Total bird abundance index

The predicted long-term mean or median relative abundance will be summed across species seasonally and/or annually to produce an index of total bird abundance, similar to that shown in Kinlan et al. (2012) for the New York Bight. This index will be calculated in two ways: (1) summing predictions of relative abundance across all modeled species without normalization, and (2) averaging the normalized relative abundances of birds (i.e., predicted relative abundance divided by the mean relative abundance), to create a more meaningful multi-species composite in which spatial patterns of rarer and more common species are weighted equally.

Functional groups

If time and resources allow, the Duke team will post-process NCCOS model outputs to aggregate them into taxonomic and/or functional groups following guidance from NROC and the Avian Working Group notes. This will be accomplished by calculating the average or median value of model predictions seasonally and/or annually for all species in a group, and mapping the result. Optionally, a version of these synthetic maps may also be produced in which species are weighted by their relative Displacement and Collision vulnerability as estimated in a recent BOEM study (Robinson et al. 2013).

3.7 Literature Cited

Kinlan, B.P., E.F. Zipkin, A.F. O'Connell, and C. Caldow. 2012a. Statistical analyses to support guidelines for marine avian sampling: final report. U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2012-101. NOAA Technical Memorandum NOS NCCOS 158. xiv+62 pp.

Kinlan, B.P., C. Menza, and F. Huettmann. 2012b. Predictive Modeling of Seabird Distribution Patterns in the New York Bight. Chapter 6 in C. Menza, B.P. Kinlan, D.S. Dorfman, M. Poti and C. Caldow (eds.). A Biogeographic Assessment of Seabirds, Deep Sea Corals and Ocean Habitats of the New York Bight: Science to Support Offshore Spatial Planning. NOAA Technical Memorandum NOS NCCOS 141. Silver Spring, MD. 224 pp.

Robinson Willmott, J. C., G. Forcey, and A. Kent. 2013. The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2013-207. 275 pp.

Zipkin, E.F., J.B. Leirness, B.P. Kinlan, A.F. O'Connell, and E.D. Silverman. 2014. Fitting statistical distributions to sea duck count data: implications for survey design and abundance estimation. Statistical Methodology 17:67-81. doi:10.1016/j.stamet.2012.10.002