Phase I Discovery & Feasibility project NNX11AR56G:
Evaluating user needs for models and decision tools to predict the impacts of climate change on the marine environment

PI Pat Halpin, Duke University

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**Phase I Discovery & Feasibility project NNX11AR56G:**
Evaluating user needs for models and decision tools to predict the impacts of climate change on the marine environment

**Goal:** explore the extension of marine animal forecasting DST to include long-term climate change capabilities:

- **GFDL TOPAZ model**
- **marine animal DST**

**ARL 0**

**Scenario development**

**ARL 1**

**interim progress**

- **End-user webinars Workshop**
  - spring / summer 2013

**ARL 2.3 – 3.1**

**Feasibility report**
- summer 2013

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Outline:

• Protected species forecasting problem
• Past / ongoing forecasting efforts
• Inclusion of climate change scenarios
• User needs assessment
• Next steps
Cetaceans (whales, dolphins and porpoises) and anthropogenic threats

Threats include

- Ship strikes
- Fishery bycatch
- Naval activities
- Anthropogenic sound

Cetaceans protected by US laws

- MMPA
- ESA
A special focus on acoustic habitats
Cetaceans (whales, dolphins and porpoises) and anthropogenic threats

What are the potential changes in oceanographic conditions, marine animal distributions and densities that will effect future management of protected species?

What are the data and forecasting needs of federal management agencies in the future?
Current Forecasting Process

(1) animal observation data

(2) ocean observation data

(3) statistical analysis & modeling

(4) spatial decision support system

GAM models of density & habitat

Temporally matched covariates
Dynamic Variables from Satellites

**Eddies from AVISO**

- Equation: \( W = s_n^2 + s_s^2 - \omega^2 \)
- Temperature: 28.0 °C
- Color Coding: Red: Anticyclonic, Blue: Cyclonic

**Fronts from Pathfinder / GHRSSST**

- Temperature: 25.8 °C, 28.0 °C
- Color Coding: Red: Optimal break 27.0 °C

- Authors: Isern-Fontanet et al (2006)
- Authors: Cayula, J-F and P Cornillon (1992)

More Robust, Dynamic Density Models
Previous NASA project NNX08AK73G goal: Upgrade DST to use more dynamic oceanographic covariates
Species data providers

Ocean data providers

NASA project enhancements

Protected Species Decision Support System

NASA project NNX08AK73G

Species observation

Ocean observation

More

Species observation

Statistical models

\[ g(\mu) = \beta_0 + \beta_1 x_1 + \cdots + \beta_m x_m \]

\[ g(E(Y)) = \beta_0 + f_1(x_1) + f_2(x_2) + \cdots + f_m(x_m) \]

GIS Tools

SDSS website

NASA project

Predicted distributions

Summary plots

Ecologically-important parameters

Algorithms

\[ u = \frac{\partial \mu}{\partial X}, \quad v = \frac{\partial \mu}{\partial Y} \]

\[ x = \frac{\partial E}{\partial X}, \quad y = \frac{\partial E}{\partial Y} \]

\[ z = \frac{\partial^2 E}{\partial X \partial Y} \]

\[ W = x^2 + y^2 - z^2 \]
Ongoing updates of density models using new covariates

New Atlantic datasets now processed for producing updated cetacean density surface models.

**New covariates**
- Time of year as a circular statistic
- Oceanographic model outputs, including mixed layer depth
- Dynamics: fronts, eddies, Lagrangian coherent structures, EKE,...
North Atlantic Right Whale

Current population estimate
~350 – 400 individuals

Foraging Grounds

Migratory Corridor

Calving Ground

Early foraging season
March - May
Survey records from 7 survey programs that operated between 1999-2012.

~287,000 km of linear distance surveyed during the focal spring season months of March-May.
Density Estimation

\[ D = \frac{n s}{L} \frac{1}{2w g} \]

- \( n \): encounters
- \( L \): line length
- \( s \): school size
- \( w \): effective strip width, \( p(distance) \)
- \( g \): probability of detecting on line, \( p(0) \)

Diagram A:
- Direction of ship travel
- Perpendicular Sighting Distance
- Radial sighting distance
- Ship
- Trackline
- Cetacean group

Diagram B:
- Radial sighting distance
- Perpendicular Sighting Distance
- Water surface
Encounter rate model

**Question**: how many animals are observed per sq km.

Must account for observer conditions and detection function.
Group-size model

**Question:** how many animals are observed in each group
Density model

The total abundance of NARW is currently estimated to be 350 – 400 animals.
Predictor variables used in spatial models

Static physiographic covariates:
- Distance to shore
- Bathymetric slope
- Distance to closest 125m isobath
- Distance to closest 300m isobath greater than 250 km in length

Climatological oceanographic covariates, computed on 8-day binning periods:
- NOAA NODC AVHRR Pathfinder 5.2 SST
- UCSB GSM merged SeaWiFS/Aqua/MERIS chlorophyll-a concentration (Maritorena et al.)
- Total kinetic energy (TKE) from AVISO DT-MADT Upd daily geostrophic currents
- Eddy kinetic energy (EKE) from AVISO DT-MSLA Upd daily geostrophic currents
- Distance to closest 1 °C SST front, computed in AVHRR Pathfinder SST using the Cayula-Cornillon (1992) algorithm implemented in the Marine Geospatial Ecology Tools software (Roberts et al. 2010)

Hypothesis: Dynamic oceanographic covariates better represent features that aggregate copepod prey...
Future forecasting needs

Research question: What remote sensing and downscaling forecasting model products will federal agency users require for the management of migratory pelagic species under changing climates?

Approach: A user needs evaluation for new models and decision support tools to forecast potential changes in marine environments and habitats under future climate change scenarios.

- Structured user needs questionnaires;
- A series of webinars and video meetings;
- An end-user workshop.
Cetacean observations, navy training areas, shipping channels and renewable energy lease blocks

How may predicted changes in ocean climate effect planning and management
Future forecasting needs

The primary questions are:
• how will responsible agencies and organizations use information on potential shifts in critical species habitats and densities;

• what types of forecasting information will be most useful to these users;

• what are the spatial, temporal and taxonomic resolutions required for long-term planning needs;

• how will end users use information on model forecast error and uncertainty;

• what data quality standards will end users require for forecast information.
Future forecasting needs

Summary of work performed to date

Our work to date has been in two areas:

(1) We have been developing IPCC class oceanographic scenarios in preparation for our end-user engagement process; and

(2) Webinar and workshop planning and preparation.
Future forecasting needs

(1) IPCC class oceanographic scenarios in preparation for our end-user engagement process;

[Images showing temperature and productivity change scenarios for Atlantic & Gulf of Mexico in January and July, and for Pacific Coast in January and July.]
Potential extension: fisheries ecology

*Example*: Are tuna and swordfish catches in the northwest Atlantic correlated with eddies and how may these features change in the future?

*What are the forecasting needs of fisheries managers?*

Hsu, A, AM Boustany, JJ Roberts, and PN Halpin (submitted). Effects of mesoscale eddies on CPUE of four fish species in the western north Atlantic. *Fisheries Oceanography.*
Potential extension: fisheries ecology

What fisheries are related to “fixed” features and which fisheries are related to climatological features?

What are going to be the “sticky fish” under climate change scenarios...

Boustany, Dunn and Halpin 2013
AAAS Symposium
Future forecasting needs

(2) webinar and workshop planning and preparation.

We have also been conducting planning and materials for the webinars and user workshop to be conducted in spring / summer 2013.

We will provide background materials, scenarios and questionnaires to representative end users from NOAA, Navy, BOEM, USF&W, NASA and other agencies prior to deployment of the video webinar(s) and in-person workshop.
Future forecasting needs

(2) webinar and workshop planning and preparation.

The webinars are intended to be used to explore general user needs issues and scenarios prior to a workshop in order to better optimize the time spent for the in-person workshop session. Also: the webinars may be able to capture a broader audience of available participants.

(Note: due to the increased risk that government agency participants may have additional travel and budget restrictions in spring 2013, we are developing contingency plans for an increased reliance on webinar interactions in lieu of in-person meetings if needed.)
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