EcoCast: Real-time data tools for dynamic fisheries management
Progress report: June 2016

Executive Summary

What we're doing EcoCast is a new fishery management tool that will predict in near real-time the spatial distributions of important highly migratory ocean species, including non-target species (such as leatherback sea turtles) and target catch (e.g. swordfish). Using this tool, fishers and managers will be able to evaluate how to best allocate fishing effort across space and time to improve fishery performance. EcoCast is being developed by a team of collaborators from several universities, NOAA, and non-profit sectors in direct collaboration with resource managers, the fishing industry and other stakeholders. The analyses for the project are being conducted by the Environmental Research Division of the NOAA National Marine Fisheries Service's Southwest Fisheries Science Center.

Why The open ocean is a dynamic environment where ocean conditions, animals and fishing vessels move across space and time. Our project aims to put a powerful modeling tool into the hands of fishermen and managers that predicts the catch and bycatch probability in near real-time as a function of changing ocean conditions to support sustainable swordfish catch with significant bycatch risk reduction. In time, this tool may allow managers to better balance ecological and economic objectives by improving accessibility to valuable swordfish fishing areas when bycatch risk is low.

How Our collaborative research team (SDSU, NOAA, Stanford, Old Dominion, University of Maryland) builds habitat models for pelagic species based on tagging and fishery observer data. These models use oceanographic data (such as sea surface temperature, chlorophyll, bathymetry, etc.) to predict each animal’s distribution under current environmental conditions. As oceanographic conditions change, the distribution of different species will also change. The full EcoCast product will integrate dynamic models that map catch probabilities for target and non-target catch species.

Latest updates We are nearing the end of Year 2 of the project. In this update, we share one of the key layers of the EcoCast product, a high-resolution predictive model for swordfish in the Southern California Bight (SCB). This model was developed based on the feedback from members of the HMSMT and NOAA scientists. This new model improves upon the monthly predictive models for swordfish at the 0.25 degree scale for the entire DGN fishing area that were presented in the March 2016 PFMC Briefing Book.

The new swordfish model is a daily, 4km predictive model for the SCB that represents the probability of swordfish catch as a function of bathymetry, bathymetric rugosity (or variability), sea surface temperature (SST) and lunar phase to predict swordfish catch probability, with red representing a high probability and blue a low probability of swordfish capture (Figure 1). The details of the models are included in the **Methods and Results** section (see Page 3). These models have been reviewed by NOAA scientists and we will be soliciting feedback on the high-resolution models from the Council, HMSMT, HMSAS, fishermen and other stakeholders at the June PFMC meeting. We are also working to find partners to formally test and validate the swordfish models.

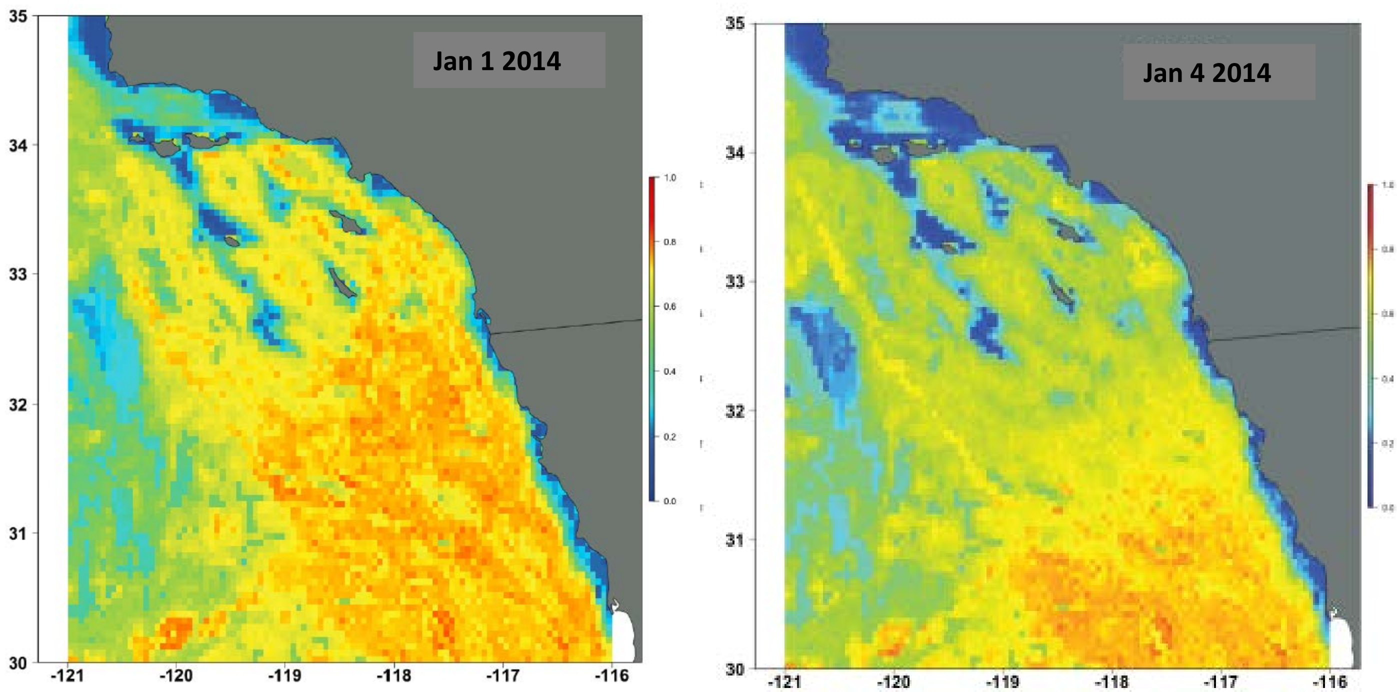


Figure 1. An image of the daily, 4km scale predictive models of swordfish catch probability in the SCB using bathymetry, bathymetric rugosity, SST and lunar phase as the key predictor oceanographic variables.

Stakeholder engagement Our analytical team continues to convene expert panel reviews with members of the HMSMT, and other NOAA scientists. Participating scientists were given an opportunity to review predictive models, ask questions, make suggestions, comments and provide comprehensive feedback on our team's products. We will continue to bring our results and findings to the Council, fishermen and other stakeholders to solicit input and expertise. We are working to find partners to formally test and validate the swordfish models.

Next steps We will continue to build the analytical components of the EcoCast product – building and validating the habitat model predictions for the three other focal species (blue shark, sea lions and leatherback turtles). Models for blue sharks and California sea lions have been developed, and these models are being revised and refined. We are also generating predictive models for leatherback turtles that can be integrated with these data layers. As we continue to develop predictive models for our focal species, we will continue to incorporate new observer data. A complementary project which will develop predictive models for hard-cap marine mammals using NOAA survey data (funded by California SeaGrant, PI:Maxwell) is underway. We continue to work to integrate Regional Ocean Modeling System (ROMS) output into the EcoCast framework.

In the next quarter, we plan to

- Launch an EcoCast website to serve as a stable and accessible platform for stakeholders to access EcoCast products. The website will also serve as means of tracking usage and solicit and record feedback. The website is being developed jointly by The Nature Conservancy (TNC) and UC Santa Barbara (McClintock Lab)
- Continue model construction for the other three focal species, and continue model refinement, incorporating time lags for a number of oceanographic variables (chlorophyll concentration, wind, sea surface temperature), improve the models' capacity to capture seasonal changes in animal distribution and ROMS data
- Integrate newly available logbook and observer data

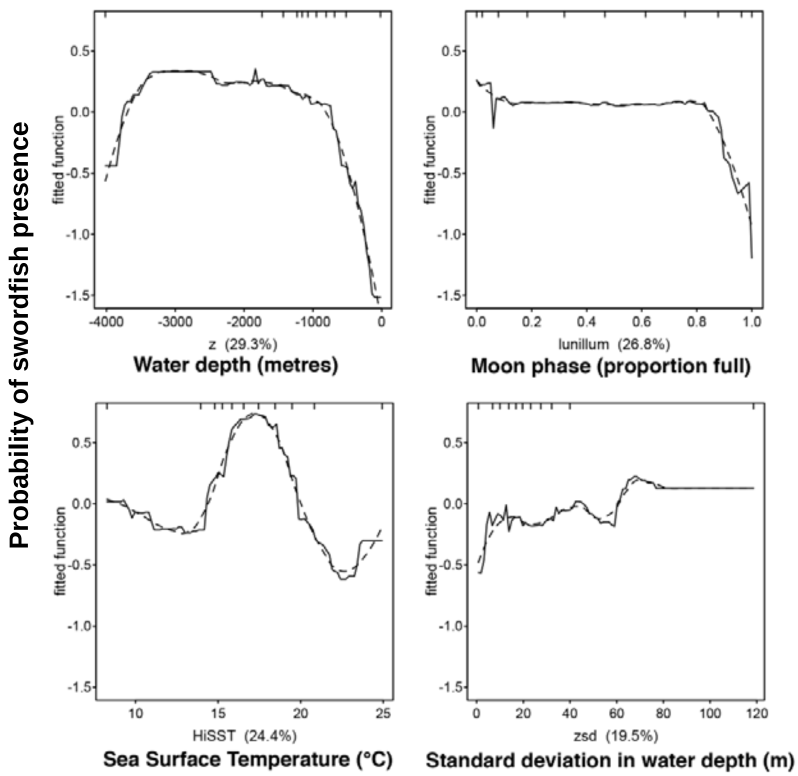
Methods and Results In this section, we provide technical details and information on the swordfish model construction, assumptions and our methodological approach. The Environmental Research Division, Climate and Ecosystems program of the Southwest Fisheries Science Center is leading the analyses for the project.

In order to provide high-resolution predictions of swordfish presence specific to the Southern California Bight (SCB), we used a subset of the DGN observer data specific to this region to inform models (121°W to 116°W; 30°N to 35°N). Models were constructed using a suite of oceanographic data with the highest spatial resolution currently available. As swordfish are known to associate with seafloor features such as seamounts and abrupt underwater topographies, we used an ultra-high resolution (2") multi-sensor bathymetry dataset known as ETOPO2v2, obtained via the NOAA World Data Service for Geophysics, Boulder (https://www.ngdc.noaa.gov/mgg/global/etopo2.html). This provided both absolute water depth, and its standard deviation over a 6"x6" moving window, for the location of each fishing set. The standard deviation of bathymetry is higher where the seafloor topography is more uneven, such as that near seamounts and submarine canyons. In combination with this bathymetric dataset, we used Pathfinder AVHRR sea surface temperature (SST) data, which has a grid resolution of 4km, for the period 1990-2011 and the more recent ultra-high resolution (1km) SST dataset produced by the NASA

Jet Propulsion Laboratory for all set locations since 2011 (http://ourocean.jpl.nasa.gov/SST). In addition, a quantitative measure of moon phase (% lunar illumination) for the day in which each set was cast was included in models, as swordfish are known to adjust their swimming depth in response to changing light penetration conditions with changing moon phase (Dewar et al., 2011). Response curves for these variables can be seen in Figure 2.

Using these measures of the oceanographic conditions at both swordfish catch and empty set locations, we used Boosted Regression Trees, a powerful ‘machine learning’ technique, to model the probability of catching at least one swordfish in each 4km cell of the study area. Model validation was carried out through leave-one-out cross-validation, a process which cycles through all years for which NOAA fisheries observer data were recorded, leaving each year in turn out of the model fitting process and then using data from that year to validate model predictions. This process yielded a cross-validation statistic of 0.7, indicating that the model is correctly predicting 70% of swordfish catch over the 24-year period. This high-resolution model can be used to predict the probability of catching swordfish in each 4km grid cell in near real-time using the ultra-high resolution SST by NASA (Figure 3).

Figure 2. Response curves for predictor variables used in the 4km Southern California Bight (SCB) swordfish model



References:
Dewar, Heidi, et al. "Movements and behaviors of swordfish in the Atlantic and Pacific Oceans examined using pop-up satellite archival tags." *Fisheries Oceanography* 20.3 (2011): 219-241

Figure 3. The daily 4km predictive model for swordfish catch probability in the Southern California Bight (SCB)