Potential Habitat Modeling for Gray Whales in the Northern Hemisphere

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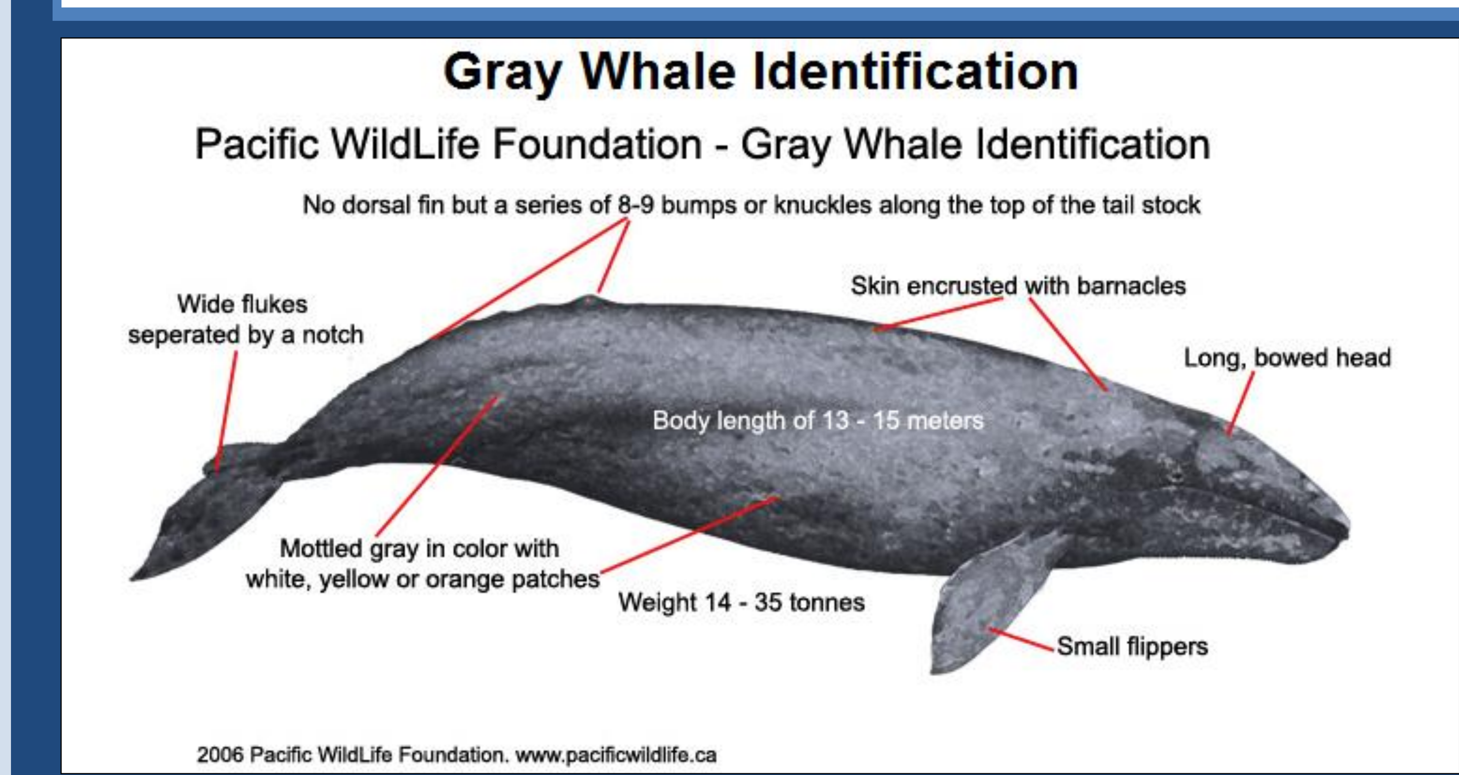
Abstract

Historically, the gray whale (*Eschrichtius robustus*) once occupied northern Pacific and northern Atlantic oceanic territories, but for the past several hundred years they have been extinct in the Atlantic. Habitat suitability modeling can be used to predict the potential habitat for a species by observing species' presence locations and correlating them with environmental variables. A new modeling technique was used to predict the potential habitat of gray whales throughout the northern hemisphere by using observational data available from sightings along the eastern Pacific coast of North America. The model shows potential continuous habitat for gray whales along the coasts of northern Asia, eastern North America, and from Europe to northern Africa. Area under the curve (AUC) values ranged from 0.93 to 0.99. Future refinements could include new recent and historical observation data, applying new environmental variables, and performing uncertainty analyses.

Background

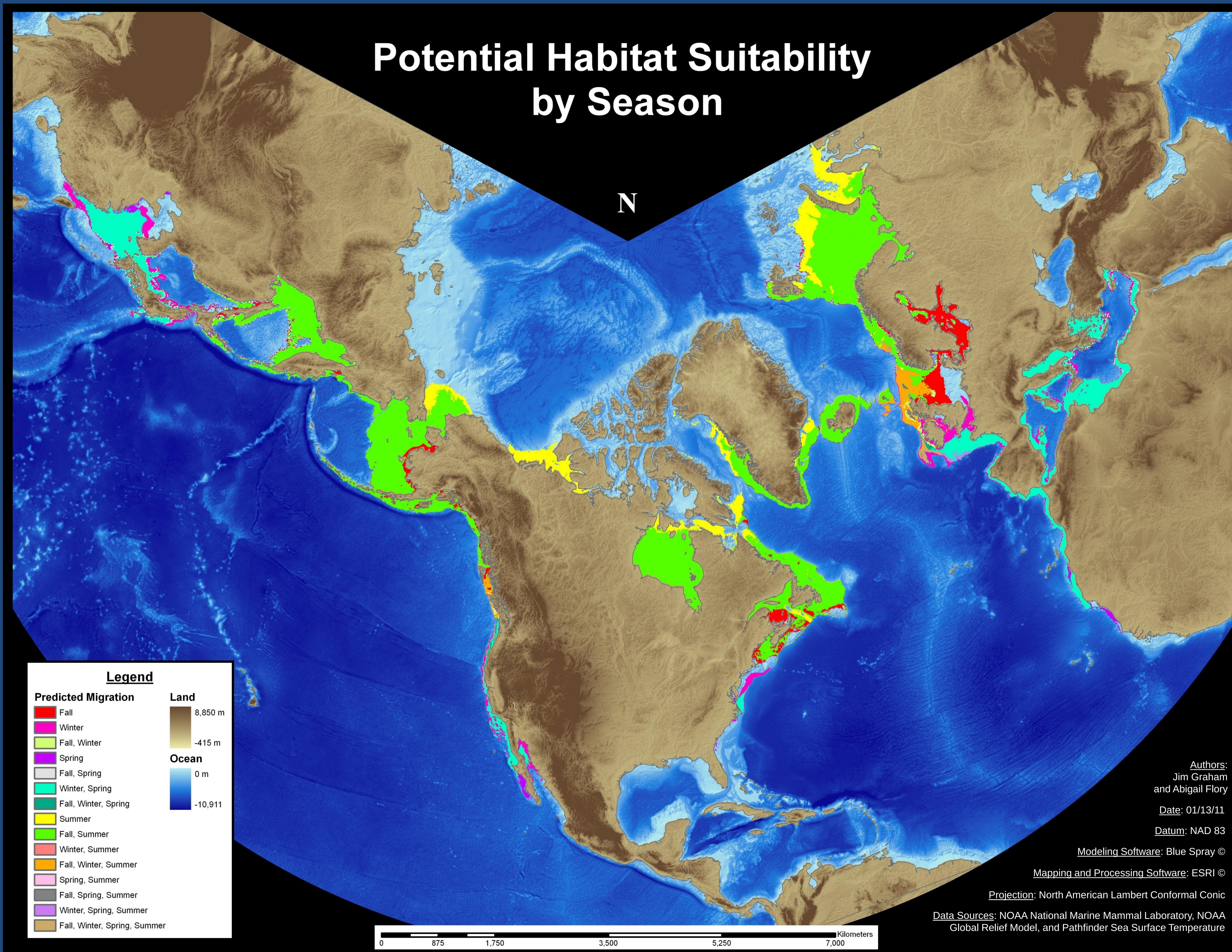
Gray whales (*Eschrichtius robustus*) are a large species of baleen whale that once inhabited the northern Pacific and Atlantic oceans. The whales were extinct in the Atlantic by the late 1700's, but survived in the Pacific. The eastern Pacific population has recovered to over 20,000 individuals, since bans on hunting were put into place, but the western Pacific population remains at several hundred individuals. Gray whales feed primarily during the summer months in higher latitudes and migrate south to calve and mate during winter months. Feeding occurs in relatively shallow coastal waters and includes benthic and epibenthic invertebrates (Swartz et al. 2006).

Potential habitat modeling (also known as species distribution modeling) can be used to identify the environmental niche that a species inhabits. These models can be used to predict the potential habitat of a species (Elith & Leathwick, 2009). There are a few models available that allow modeling based on presence only data (e.g. Phillips et al., 2006). These can be difficult to interpret based on biological theory and can be hard to visualize in environmental space (Graham, & Hijmans, 2006). Our goal was to model gray whales throughout their current and potential habitat.

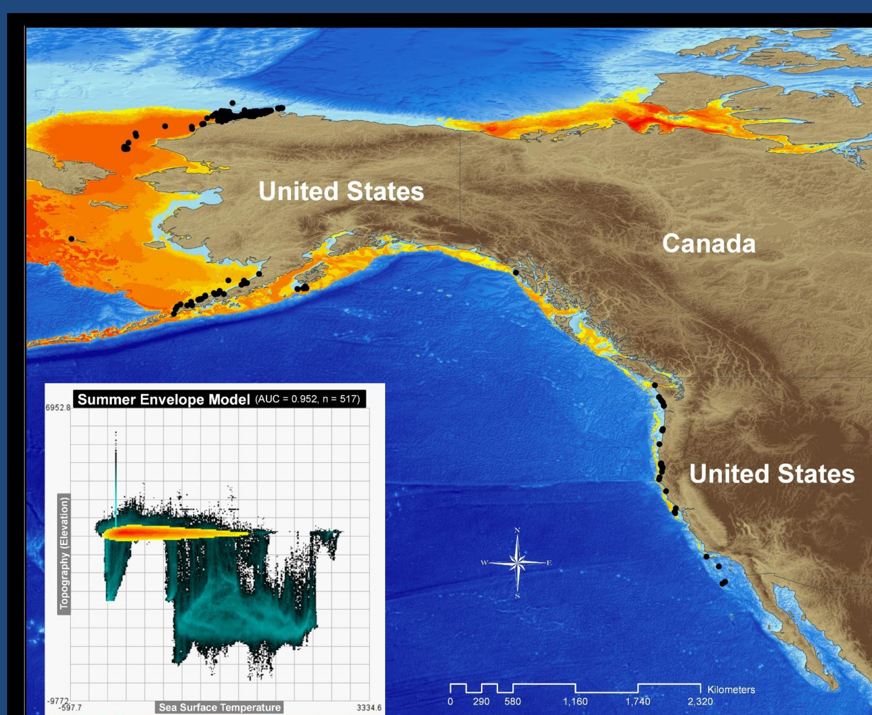


Methods

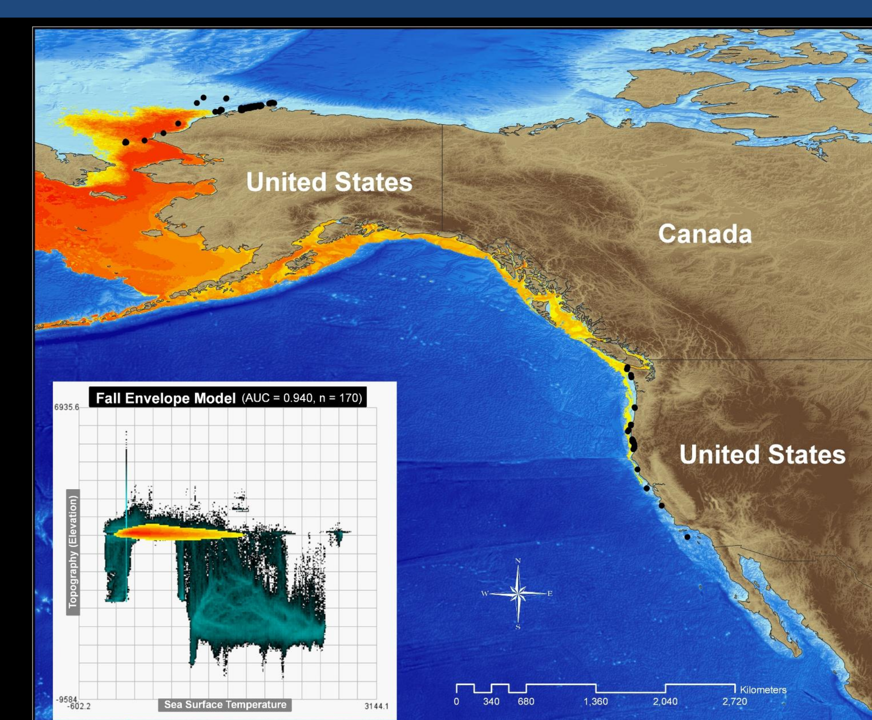
Coordinates of gray whale observations were divided into seasons and correlated with values from two environmental predictor layers within the sample area: bathometry and sea surface temperature. A Bezier surface was centered over the point of highest sighting occurrence density, and eight additional control points at 10% density were placed around this center point. A sigmoidal transfer function was used to create probability densities ranging from 1 (highest density) to 0 (periphery of the model). The control points for the Bezier surface where then manually positioned to optimize the AUC values while maintaining a model that matches the expected niche of gray whales.



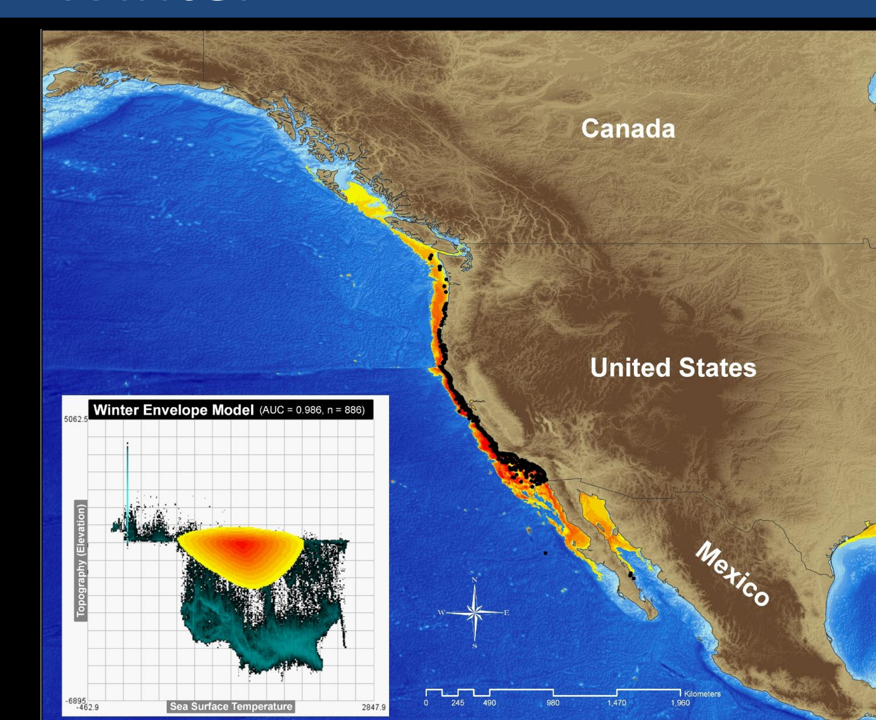
Summer



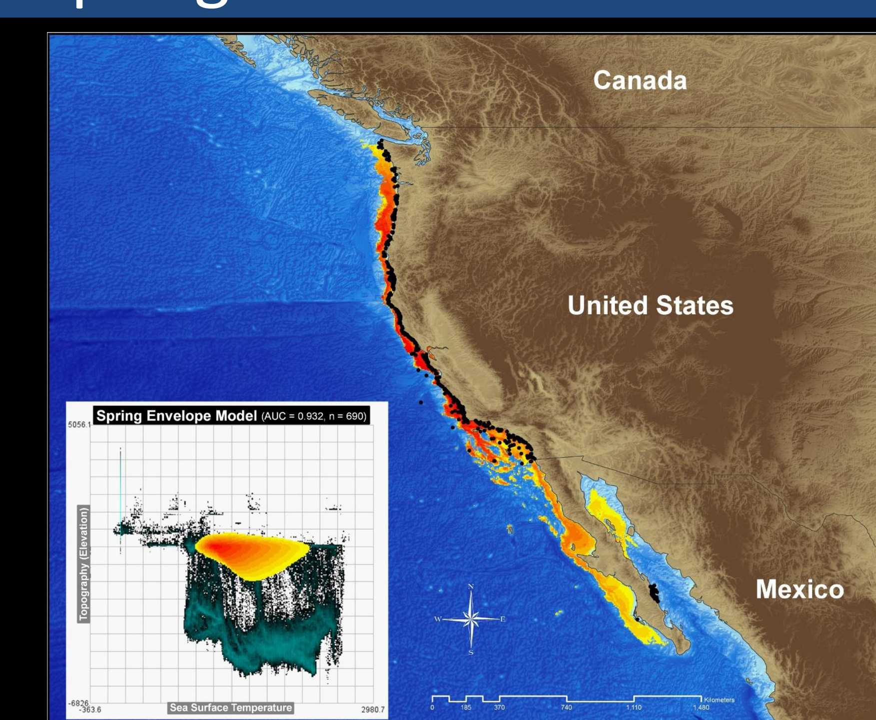
Fall



Winter



Spring



Maps for each of the four seasons can be found above. Each map shows predicted habitat, original sample points, and an inset with the environmental space and the predicted model. These models where used to create four seasonal northern hemisphere habitat probability maps, and then combined to create the entire northern hemisphere potential habitat map. Connectivity was assessed by applying a 20km buffer to the modeled areas and removing pockets of no overlap and isolation. Habitat areas were color coded by season and can be found in the final map at top center.

Data Sources	
Gray Whale Sightings † ‡	NOAA BWASP aerial survey data. Laake, J., A. Punt, R. Hobbs, M. Ferguson, D. Rugh, and J. Breiwick. 2009. Re-analysis of gray whale southbound migration-surveys 1967-2006. NOAA Tech. Memo. NMFS-AFSC-203.
Sea Surface Temperature *	NOAA's National Oceanographic Data Center; derived using NODC/RSMAS AVHRR Version 5.0 Pathfinder 4km SST data, day and night values combined and gap-filled.
Bathymetry °	ETOPO1 Global Relief Model from NOAA's National Geophysical Data Center.

† http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php
‡ http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-203.pdf
* http://www.nodc.noaa.gov/sog/pathfinder4km/userguide.html
° http://www.ngdc.noaa.gov/mgg/global/global.html

Results

Occurrences in environmental space showed that gray whales prefer areas with shallow water. The potential habitat was similar in the summer and fall when gray whales feed along the large coastal shelf surrounding Alaska and, although fewer, along the coast of California. During the winter and spring, all of the observations were along the coast of the lower 48 states and Mexico, but depth of habitat varied more than during the fall and winter.

The seasonal models produced Area Under the Curve (AUC) values from 0.93 to 0.99 and appeared to correlate well to documented behavior of gray whales. The combined map produced potential connected habitat along the eastern and western coasts of both the Pacific and Atlantic oceans.

Season	AUC Values
Fall	0.94
Winter	0.99
Spring	0.93
Summer	0.95

Conclusions

The model shows gray whale potential habitat throughout their existing and historical range. The Hudson Bay and the Barents sea are not documented as gray whale habitat, but these seem plausible. While the model produces a reasonable map of potential gray whale habitat, additional data should be compiled and further modeling performed to refine the model results. This type of modeling is potentially important to evaluate areas for management of gray whales and can be extended to include climate change scenarios.

References & Acknowledgements

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