Environmental Studies Program: Studies Development Plan | FY 2024–2025

Field	Study Information
Title	Using Very High-Resolution Satellite Imagery to Detect Cetaceans
Administered by	Office of Environmental Programs
BOEM Contact(s)	Timothy White (timothy.white@boem.gov)
Procurement Type(s)	Interagency Agreement
Performance Period	FY 2024–2027
Final Report Due	TBD
Date Revised	May 15, 2023
Problem	Data on cetacean distribution are needed at spatial and temporal scales that are challenging to collect using existing methods. Satellite imagery has the potential to provide the required information but there are a number of barriers that need to be overcome before this approach can be operationalized.
Intervention	Work with collaborators to create an effective whale detector. Package together libraries of high-resolution satellite imagery annotations for each species of interest that are currently under development into a publicly available web-based interface for detecting objects of interest from very high-resolution satellite imagery.
Comparison	Vessel and aerial surveys are challenging to implement over large spatial scales, in remote areas, and during seasons with poor weather. While passive acoustic monitoring provides valuable information on species occurrence in specific locations or time periods, extrapolating to overall distribution is challenging, and inference is limited to vocalizing animals.
Outcome	Further the development of using very high-resolution satellite imagery to detect cetaceans.
Context	North Atlantic wind planning areas and Alaska lease areas.

BOEM Information Need(s): Information on cetacean abundance and distribution is needed to assess overlap between key species and potential oil and gas activities in Alaska waters and BOEM wind energy areas throughout the U.S. east coast. Vessel and aerial surveys have long been used to provide information on marine mammal density and distribution. Still, they are challenging to implement over large spatial scales, in remote areas, and during seasons with poor weather. While passive acoustic monitoring provides valuable information on species occurrence in specific locations or time periods, extrapolating to overall distribution is challenging, and inference is limited to vocalizing animals. The use of satellite imagery has the potential to provide information on abundance and distribution during seasons and in areas that are currently challenging, or prohibitively expensive, to survey and are needed to meet regulatory requirements under the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and National Environmental Policy Act (NEPA). Focal species for this study include endangered cetaceans in Alaska (Cook Inlet beluga whales, bowhead whales) and the North Atlantic (North Atlantic right whales) as well as humpback whales in both areas. These cetaceans are of critical

interest due to their status under the Endangered Species Act and the overlap of their range with areas of increased anthropogenic impact such as oil and gas exploration, fishery entanglement, and development of offshore wind farms; bowhead whales are an important cultural resource to Alaska Natives.

Background: Information on cetacean distribution is needed at a temporal and spatial scale that is not currently achievable using existing methods. Several recent publications have demonstrated that it is technologically feasible to identify whales in very high-resolution (VHR) satellite imagery. The availability of VHR imagery is expected to dramatically increase in the coming years with the launch of the new Maxar's Legion constellation of satellites in 2023 that have the ability to capture 5 million sq km a day (~3% of the earth) at a resolution of 31 cm and a revisit rate up to 15 times a day. However, there are significant barriers to using these data in an operational capacity to understand cetacean distribution, including access to satellite imagery, wind, cloud cover, and availability of the animals at the surface. This study outlined here is part of an ongoing collaboration between BOEM, NOAA/NMFS and NOAA's Alaska Fisheries Science Center (Khan et al. 2023). Several recent technological advancements have brought the use of VHR satellite imagery to the cusp of operational feasibility:

1. The launch of the Maxar WorldView-3 satellite with 30 cm resolution.
2. The planned launch of the Maxar Legion program with dramatically improved revisit rates.
3. Proof of concept academic studies.
4. Advances in deep learning tools enable semi-automated identification and classification of objects.

Much of the work in this field is being led by the Geospatial Artificial Intelligence for Animals (GAIA) initiative, which brings together an extraordinary coalition of organizations to tackle the challenge of designing a large-scale operational platform to detect whales from earth-orbiting satellites, including government agencies (National Oceanic and Atmospheric Administration (NOAA), U.S. Naval Research Laboratory (NRL), the Bureau of Ocean Energy Management (BOEM), and the U.S. Geological Survey (USGS)), academia (British Antarctic Survey (BAS), University of Edinburgh), and the private sector (Microsoft AI for Good Research Lab, MAXAR). GAIA has received support over the past few years in the amount of $275,000 from various grants to NOAA Fisheries, and $60,000 from the Naval Research Laboratory under sponsorship by ONR Marine Mammal Biology Program. Preliminary analyses associated with these exploratory projects helped to advance the basic understanding of the workflow required for an Artificial Intelligence/ Machine Learning (AI/ML) framework to detect whales from space. Over the past three years, this investment has supported numerous efforts, including :

- The development of software (Picterra) for annotating satellite imagery.
- A statistical hypothesis test on surface whales, submerged whales, and background pixels on VHR imagery as a proof-of-concept, resulting in an analysis of whale detections based on spectral signature.
- The leveraging of anomaly-based detection methods used for vessels in VHF imagery for the detection of large marine mammals. These methods proved to be successful for detecting large marine mammals, highlighting current capabilities and pipelines that could be used for this effort.

- The development of a neural network-based detection algorithm for whales. A total of 730 whale signatures and 9,300 background signatures were extracted to provide training and testing data. This work is ongoing and will support GAIA development.
- Maxar GeoHIVE crowdsourcing annotation and the development of an annotation workflow for satellite imagery using ArcMap and ArcPro.
- The integration of detection algorithms into an end-to-end, Marine Mammals from Space tool suite to support GAIA efforts. This will allow users to upload satellite imagery, pre-process imagery for likely whales using automated algorithms, present likely whales for users for verification, and store whale chips in a database. This part of the project will feed into a classification tool that for identifying whales to the species level.

As is the case with the annotated reference library, the detection models are still preliminary, and classification models have not been developed. Further work is needed to create this workflow to build the library and systems required for an operational framework.

Objectives:

1. Development of an automated pipeline for routine identification of cetaceans in VHR satellite imagery for key species including the development of an annotated image library including infrastructure support for cloud computing and/or on-premises GPU machines and software.
2. Development of a database (including the development and maintenance of a web-based interface) where users can upload, view, and train sample images of marine mammals for algorithm development and storage of marine mammal detections.

Methods: Efforts to create an effective whale detector will be pursued by multiple collaborators, including Microsoft and NRL. Creating an extensive library of high-resolution satellite imagery annotations for each species of interest is underway with three different methodologies (Maxar GeoHIVE crowdsourcing campaign, in-house manual annotation, and via an online annotation tool that serves up image chips resulting from an anomaly detector). These components will be packaged together into a publicly available web-based interface for detecting objects of interest from VHR satellite imagery, allowing users to connect with their cloud computing resources (image storage containers and machine learning servers). Annotations will be used to refine machine learning models in an active learning process. These algorithms will be made opensource as much as possible and integrated into the operational system for whale detection. Funding will support staff to operationalize this AI/ML annotation system including project management and annotation labor at NOAA Fisheries, and scientific and software engineering support at NRL. Funding will also be used to host an interagency working group to meet in person to scope out the vision for the operational system and workflow bringing together expertise from BOEM, NOAA, NRL, Microsoft, BAS, and others.

Specific Research Question(s):

1. Can population estimates and localized space use be effectively assessed using satellite imagery and what might limit the effectiveness of this approach?
2. What is the best way to operationalize the detection of cetaceans from VHR satellite imagery to expand our ability to monitor marine mammal presence, especially in areas of interest to oil and gas exploration, offshore wind energy, fishing gear entanglement and aquaculture?

Current Status: N/A

Publications Completed: N/A

Affiliated WWW Sites:

Geospatial Artificial Intelligence For Animals | NOAA Fisheries

GitHub - microsoft/whales: An active learning pipeline for identifying whales in high-resolution satellite imagery.

References:

Cubaynes HC, Clarke PJ, Goetz KT, Aldrich T, Fretwell PT, Leonard KE, Khan CB. 2023. Annotating very high-resolution satellite imagery: a whale case study. MethodsX. 10:102040.

Khan CB, Goetz KT, Cubaynes HC, Robinson C, Murnane E, Aldrich T, Sackett M, Clarke PJ, LaRue MA, White T, at al. 2023. A biologist's guide to the galaxy: leveraging artificial intelligence and very high-resolution satellite imagery to monitor marine mammals from space. Journal of Marine Science and Engineering. 11(3):595.