A Novel Technique to Detect Epipelagic Fish Populations and Map their Habitat

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LONG-TERM GOALS

The ultimate goal of this project is to substantially improve our understanding of the relation between ecologically important key fish species (e.g. sardine and albacore) and the physical environment by collecting synoptic measurements with improved spatial and temporal resolution of observations.

OBJECTIVES

Our partnership program is striving to develop a new method for detection of fish and synoptically mapping their environment at nested spatial and temporal scales. This new technique involves employing aerial data collection techniques (which are able to collect data at a much larger range of temporal and spatial scales than traditional methods) and coupling them with directed and coordinated ship-based observations, buoy data, and satellite-derived information. The nested array of observations are being analyzed and modeled in a GIS-based environment to provide qualitative and quantitative views of habitat- and behavioral-induced fish distribution patterns.

APPROACH AND WORK PLAN

1) The overall objective of this work is to develop a new technique to detect epipelagic fishes and map their habitat and to test this technique in the EEZ of Oregon and Washington. The secondary objective is the analyze the array of spatial data collected to better understand the connection and affects of habitat and fish behavior on fish detection and distribution. The technique combines data from satellites, aircraft, ships, and moorings. Each platform covers a unique set of spatial and temporal scales, and each instrument has its own advantages and disadvantages. A technique combining data from multiple platforms can be much more powerful than any one alone.

2) James Churnside of NOAA ETL will be responsible for overall coordination of this project. He will also be responsible for the LIDAR component and for the investigation of automatic species identification from airborne video. An engineer (James Wilson) and a part-time undergraduate student (Holly Sewell) will work on the LIDAR effort. Richard Brodeur of NOAA Fisheries will be responsible for the coordination of this effort with the ship surveys, including obtaining data from those surveys, and for contributing to the synthesis effort. Evelyn Brown of the University of Alaska, Fairbanks will be responsible for obtaining satellite data, coordination with the fishing industry, including spotter pilots, and contributing to the geostatistical analysis and synthesis efforts. Kelly Benoit-Bird of Oregon State University will be responsible for the acoustic moorings and processing of all acoustic data. John Horne of the University of Washington will be responsible for development of techniques for optimally combining LIDAR and acoustic data.

3) In the upcoming year, we will: complete the processing and analyses of the data from the two field experiments, and write up the results for publication.

WORK COMPLETED

This year, we completed the second field campaign of the project. Like the first year, we obtained data from satellites, an aircraft, a ship, and fixed moorings. However, there were significant differences. The study was done in June instead of July to obtain data under different oceanographic conditions. The second polarization channel was added to the NOAA Fish LIDAR, providing the first dual-polarization measurements of fish and zooplankton in this type of study. The at-sea LIDAR calibration technique was modified to make it easier for the pilots to hit the calibration target. Also, the moorings were placed near the edge of the Columbia River plume, and this very dynamic area was intensively covered by the ship and the aircraft.

Figure 1 shows the clearly-visible Columbia River plume near the mooring site, where the water depth varied between 115 and 130 m. The survey design (Fig. 2) consisted of a small-scale grid pattern composed of (4) one nmi long parallel transects spaced 0.25 nmi apart in a north-south direction followed by another 4 in an east-west direction conducted continuously over a 24 hour period. The LIDAR flights followed the same grid pattern only once every 1 to 2 hours, 2 to 3 times during daylight hours and 2 to 3 times during evening hours. Four, upward looking echosounder acoustic moorings were deployed at the corners of the grid survey. Each mooring consists of 200 kHz Simrad transducers, housed electronics, flotation, acoustic releases, and sacrificial weights.

Fig. 1. A strong frontal boundary indicating the Columbia River Plume visible from the F/V Frosti near the mooring box site.

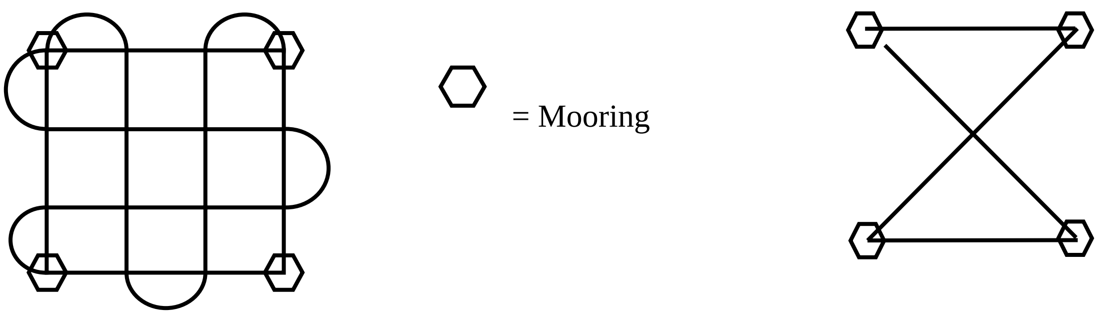

Fig. 2. Survey design showing moorings and tracks followed by the ship and aircraft.

Our original plan called for the use of the relatively new NOAA Fisheries Research Vessel, the Oscar Dyson, that would be able to conduct all the necessary at-sea sampling for our study. Less than 2 weeks before our scheduled departure, the ship had engine problems and had to go into the shipyard, thus leaving us with no apparent options to ground-truth the LIDAR data. NMFS headquarters was alerted to the problem and made available funds to charter a commercial fishing vessel in place of the NOAA ship, which we were able to do despite the short time frame available. Scientists from the National Marine Fisheries Service Northwest Fisheries Science Center, University of Washington, and Oregon State University conducted the research cruise aboard the FV *Frosti* (an 80 meter chartered fishing vessel) from 1 June to 8 May 2006. The cruise covered coastal marine waters of Oregon and Washington with a focus just north of the Columbia River plume (where Columbia River flows interact with the California Current).

Shipborne acoustic echosounder surveys were conducted over the mooring box during daytime, nighttime, dawn, and dusk in order to resolve the diel patterns of fish and plankton behavior. These surveys will serve as a comparison with the acoustic moorings to integrate data collected over different time and spatial scales. In addition to ship-borne acoustic surveying, a CTD and Tracor acoustical profiling system (TAPS) were used to simultaneously sample hydrographic conditions and acoustically profile zooplankton distribution. A total of 10 CTD/TAPS profiles were conducted during the ship-board plankton and fish sampling. These data will supplement 16 plankton collections by Bongo nets and 8 fish trawls.

The NOAA Fish LIDAR, an infrared radiometer for sea-surface temperature, and a visible radiometer for ocean color were flown on one of the NOAA Twin Otters. The flights included large-scale surveys to put the ship-based survey results into a larger perspective, calibration flights, day and night flights to measure the dual-polarization scattering characteristic of different water masses, and repeated flights over the ship and the moorings in the intensive study area.

We have obtained spotter pilot reports and fishing records from the 2005 field season. These will be used to investigate the effectiveness of spotter pilot reports in multiple-platform, adaptive-survey design and as ground-truth information for the LIDAR data. Corresponding data are not available for the 2006 field season, because the fishery did not start as early as expected.

RESULTS

The 2 years of field studies have provided a very rich data set that we have only begun to analyze. However, some interesting preliminary results have been obtained.

Preliminary moored acoustic and LIDAR data analysis from the first field season (Fig. 3) have shown that the dominant signal was a strong diel pattern in both.

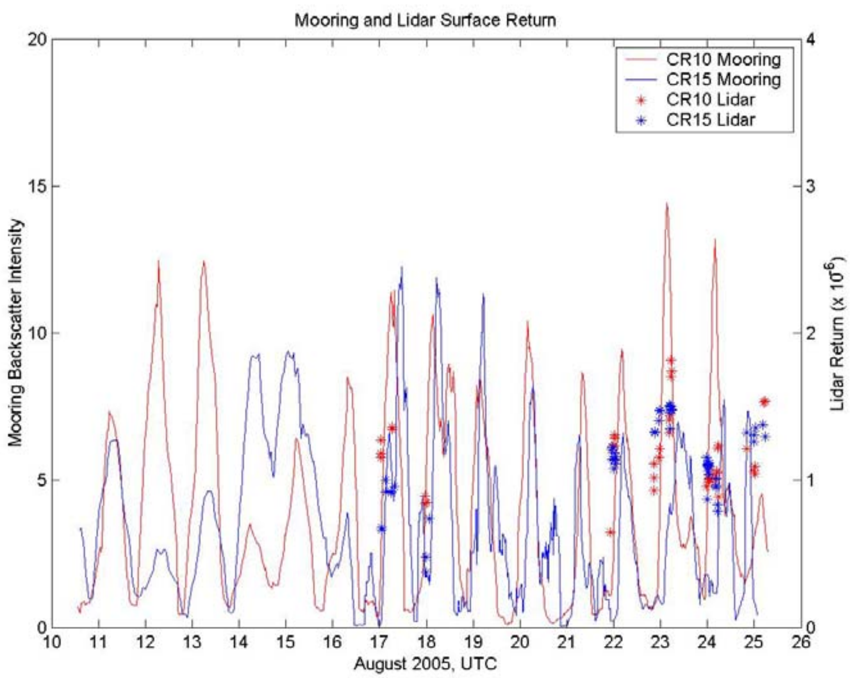

Fig. 3. Preliminary comparison of acoustic and LIDAR data showing a strong diel pattern present in both.

Surface fish trawl samples collected during ship-board surveys indicated a difference in the biology of this June cruise compared to last years August sampling cruise in the same region. Fewer bait fish (sardine and anchovies) were present but many more juvenile salmon (Fig. 4) were caught which may reflect a difference in the timing of the study.

Fig. 4. Fish trawl samples caught during ship-borne fish surveying over mooring sites dominated by juvenile salmon.

We have also begun a Geographic Information System (GIS) analysis of the data (Fig. 5). Along the flight paths, SST, chlorophyll concentration, and information on the distributions of surface nekton were obtained. In addition, satellite determined SST and chlorophyll concentrations were used to expand the area of interest sampled with the LIDAR. Data were then input into a GIS for spatial analyses. A geostatistical approach was used to create near-synoptic daily SST maps to determine the locations of thermal fronts. Once available, a similar method will be used to determine the locations of the highest concentrations of chlorophyll. The locations of nekton are being compared and analyzed with respect to their proximity to the SST fronts and high chlorophyll concentration areas. There is a high degree of spatial and temporal variability in the northern California Current, yet the locations of thermal fronts are known to be important to many species. Thus, identifying the spatial patterns of marine organisms relative to characteristics within the surface environment will provide valuable information that will yield better-informed management decisions and has implications for marine conservation and the design of marine reserves. Preliminary results suggest that even slight SST fronts (0.3°C/km) are important habitat components of the marine environment in this area. The next step in the analysis is to include the chlorophyll data which will provide detailed information on the relationship between surface nekton and physical and biological properties in the northern California Current.

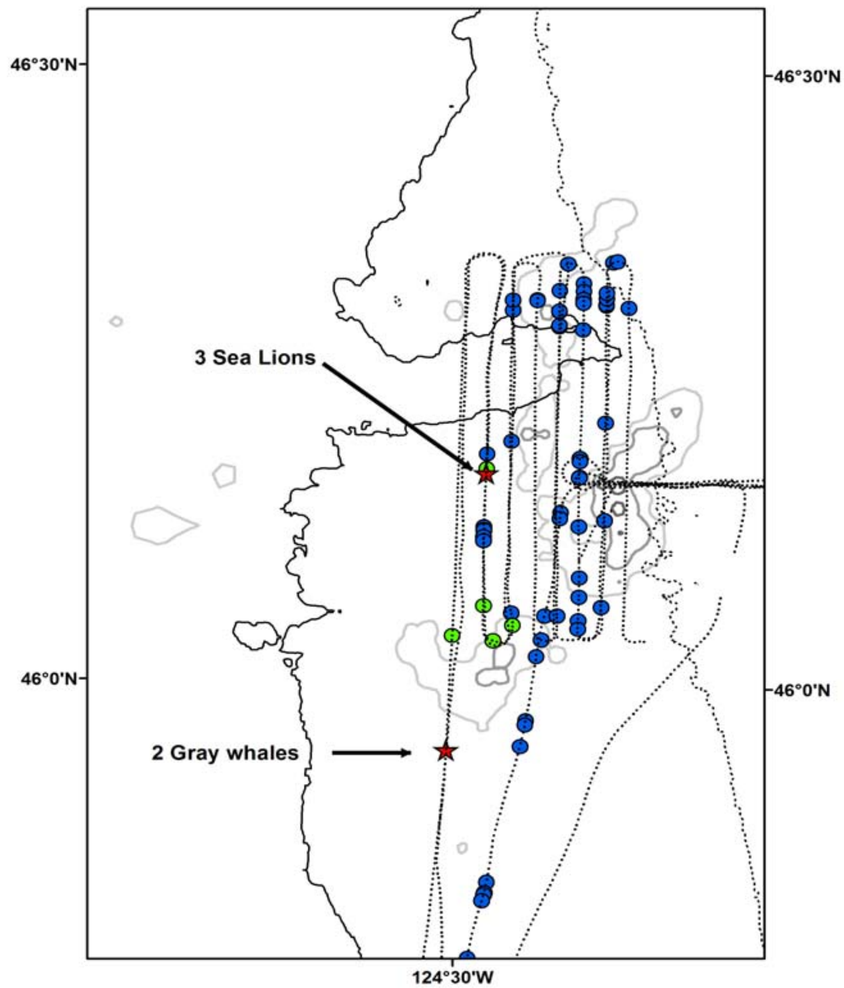

Fig. 5. Multilayer GIS map showing 200-m isobath (dark line), SST fronts (grey lines), flight track (dashed line), and locations of fish schools (blue), individual large fish (green), and marine mammals (red).

While no journal articles have been submitted for publication yet, three conference presentations have been made:

A. M. Kaltenberg, K. J. Benoit-Bird, R. D. Brodeur, J. K. Horne, and J. H. Churnside, "A Study of Sardines in the NE Pacific Using Multiple Platforms and Technologies," Ocean Sciences, Honolulu, Hawaii, February 20-24, 2006.

J. K. Horne, J. H. Churnside, and P. Adam, "Potential Integration of Acoustic and LIDAR Backscatter Data," Ocean Sciences, Honolulu, Hawaii, February 20-24, 2006.

D. C. Reese, R. D. Brodeur, J. H. Churnside, and R. T. O'Malley, "Identifying the relationship between sea surface temperature and nekton distributions in the northern California Current," American Fisheries Society Annual Science Meeting, Lake Placid, New York, September 10-14, 2006.

IMPACT AND APPLICATIONS

Quality of Life

This program has strong support from the sardine fishing industry in the study area. The results from this study will be used to ensure the industry and resource managers have the best information possible on which to base resource allocation

Science Education and Communication

This project is partially supporting a post-doctoral position and a graduate student at Oregon State University and a graduate student at the University of Washington.

RELATED PROJECTS

This work is related to a North Pacific Research Board program involving Churnside, Horne, Brown, and others to investigate combined aerial and surface techniques to survey forage fish in the SE Bering Sea. That program does include a habitat component, and the different target species will require different techniques. Many of the general principles, however, are related.

This work is related to ongoing surveys by the Northwest Fisheries Science Center, NOAA, to estimate the abundance and distribution of the dominant pelagic commercial species, including sardines and tuna and their relationship to physical oceanographic factors such as upwelling and Columbia River plume fronts. Funding for these surveys comes from NOAA and the Bonneville Power Administration.

This work is related to experimental LIDAR surveys of menhaden done in September 2006 in Chesapeake Bay and the coastal Atlantic waters between the mouths of Chesapeake and Delaware Bays. This work was funded by the Maryland State Department of Natural Resources.

The comparison of LIDAR and acoustic sampling techniques for assessing biology in this work is strongly related to the collaboration between Benoit-Bird and Concannon and Prentice (NAVAIR). Concannon and Prentice are funded through ONR under the LOCO DRI and Benoit-Bird through the YIP program. This project seeks to compare airborne lidar and ship and moored acoustics, focusing primarily on fish as targets while the LOCO project compares ship based lidar with ship and moored acoustics primarily focusing on plankton as targets.