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

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Award Number: BOP - trans 30306, plan 487-39
http://www.etl.noaa.gov/fishlidar

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. A simplified theoretical treatment of polarization lidar for fisheries applications will be submitted for publication. A geostatistical analysis of the relationship between the distribution of fish and oceanographic fronts will be completed and submitted for publication. A comparison of the spatial and temporal characteristics of fish schools will be completed and submitted for publication. An analysis of the scale dependence of the variability of the fish distribution will be completed and submitted for publication. An investigation into the use of computer animation to integrate information from multiple sensors with different temporal and spatial measurement scales will be completed and, if successful, submitted for publication.

WORK COMPLETED

In this year, we have completed most of the data analysis for the individual techniques, and started working on the intercomparison and combination of techniques. Examples of preliminary results are presented in the next section of this report. Several journal articles are in preparation on various aspects of the program. The third field season that was originally proposed was canceled because of budget cuts.

RESULTS

For the two years of field surveys data were collected by direct sampling, moored acoustics, ship mounted acoustics, airborne radiometers, airborne lidar, visual observations, and satellite radiometers. These were combined in several different configurations to take advantage of strengths and weaknesses of each technique. In the most comprehensive combination (Fig. 1), acoustic moorings were placed at the corners of a 1 nautical mile square near the shelf edge on the northern edge of the Columbia River plume. The surface ship was used to make echosounder measurements, CTD casts, and trawls within this box. The aircraft was used to make lidar measurements within a 10 nautical mile box around the smaller box.

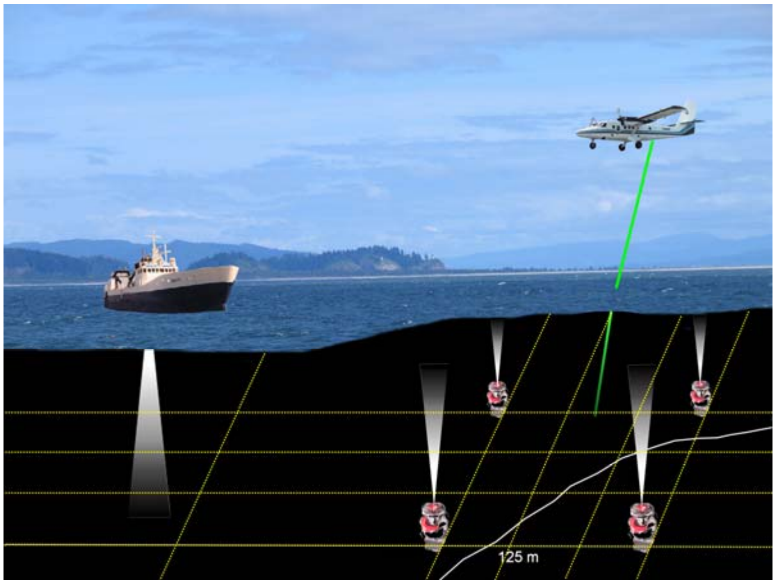

Fig. 1. *Conceptual drawing of the combination of moorings, ship, and aircraft near the mouth of the Columbia River. The white line shows the position of the 125 m depth contour, and the yellow lines the survey tracks.*

The four acoustic moorings are able to provide the depths and times of each school that passes through the beam. Fig. 2 shows that distribution of schools. During the day, there is a group of schools near the surface and a second group of schools that is closer to the bottom. At night, there are few schools passing through the beams. Trawl data tell us that the schools are mostly sardines and anchovies. The lidar provided the spatial distribution of schools in the near-surface group over a wider spatial area (Fig. 3). This shows that most of the schools were east of the inner square, with another concentration just to the southwest. Consistent with the mooring data, almost all of the schools were observed during the day.

The mobile acoustic survey provides spatial distribution of biomass from ~10m to the sea floor. When combined with other sampling technologies, the water column can then observed over a range of spatial and temporal scales. Time and space are confounded more in the mobile acoustic survey than in the airborne lidar survey. By comparing lidar and moored acoustic data, the spatial variability between mobile acoustics, moored acoustics, and lidar can be quantified as a function of time. Figure 4a shows an acoustic backscatter curtain from a grid cruise track surveyed from the vessel. Mobile acoustic data (38 and 120 kHz) from the loop in the northwest corner of the grid (red circle) is ‘straightened’ in figures 4b and 4c between 22:56 and 23:14 PDT. The blue line marks the approximate location in space of the upward looking moored transducer. An echogram from the mooring over approximately the same time period is shown in Fig. 4d.

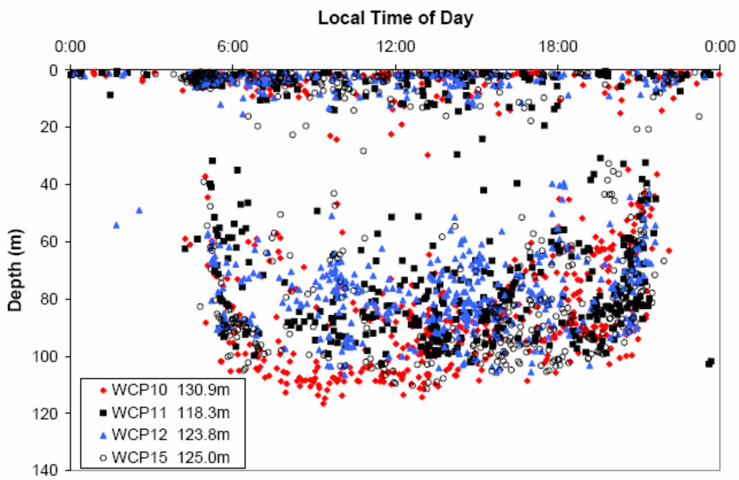

Fig. 2. *Distribution of schools from the 4 moorings by depth and time of day. Mooring numbers correspond to the NW, NE, SE, and SW corners, respectively.*

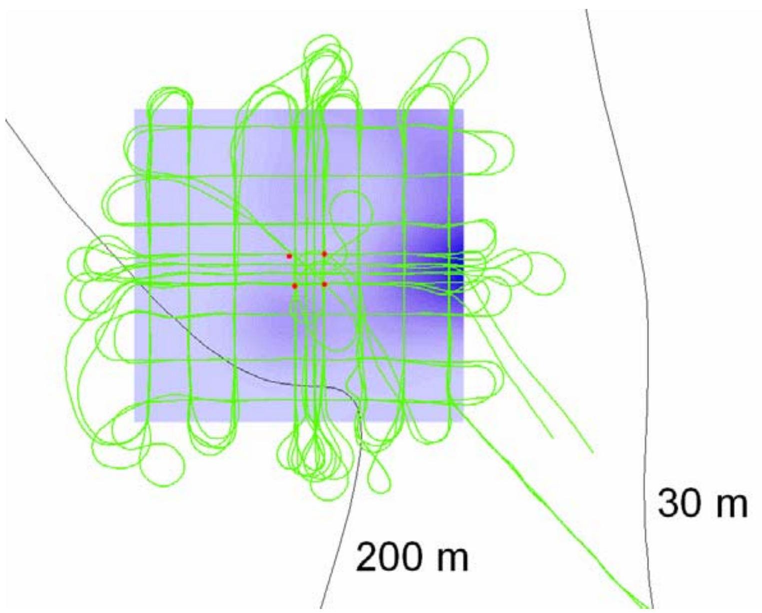

Fig. 3. *Mooring locations (red), lidar flight tracks (green), relative distribution of near-surface schools lidar return strength from none (light blue) to the maximum (dark blue), and 200 m and 30 m isobaths (gray).*

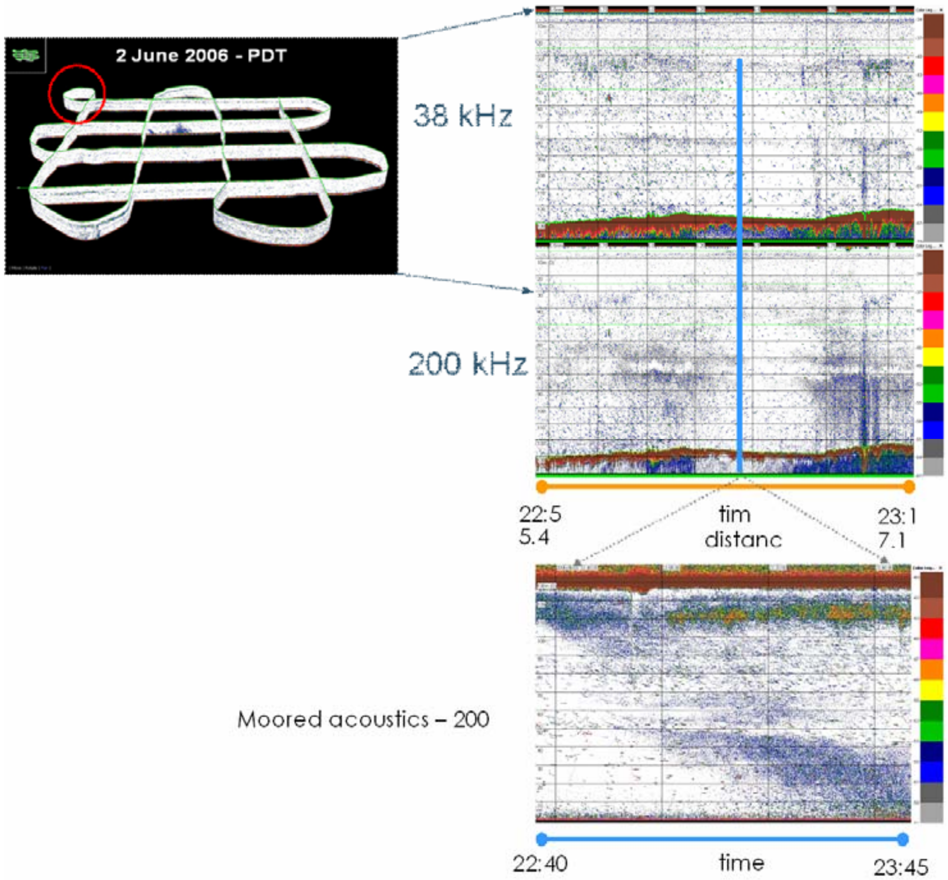

Fig. 4. *Integrating acoustic data streams by combining a) mobile acoustic surveys in a grid that compile b) echograms at 38 and 120 kHz, with c) moored acoustics at 200 kHz recording in the northwest corner of the grid.*

Sea surface temperature (SST) and primary production are important habitat components for many marine fish species. We used airborne radiometers, airborne lidar, and daily satellite SST data to examine the relationship between SST fronts and the distribution of fish. After determining the locations of SST fronts, we calculated the distances of fish locations to SST fronts and compared this with distances of random points along the flight paths to determine if the fish were found statistically closer to the fronts then would be expected by chance (Fig. 5). Results indicate that fish schools often associate with SST fronts, despite the fact that the SST fronts are ephemeral in space. In general fish schools tended to be nonrandomly distributed over the shelf with respect to the thermal structure of the surface water. Additionally, we compared chlorophyll concentrations within and outside SST frontal regions and found that chlorophyll concentrations tended to be higher within the frontal regions. Results suggest that even slight SST fronts (0.2°C/km) are important habitat components of the marine environment in this area.

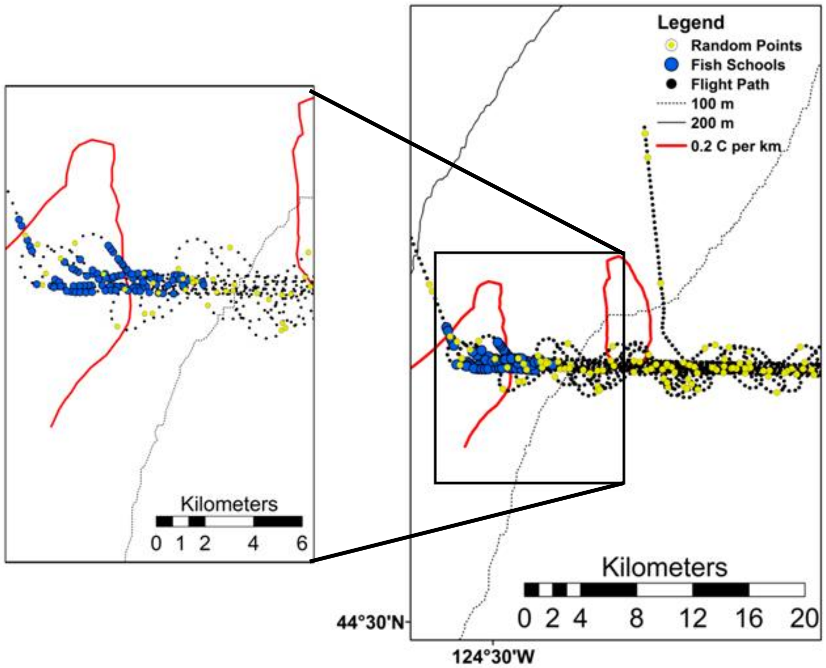

Fig. 5. *Multilayer GIS map showing 100 and 200-m isobaths (dotted and dark line, respectively), SST fronts (red lines), flight track (heavy dashed line), locations of fish schools (blue), random points along flight path (yellow).*

IMPACT AND APPLICATIONS

Quality of Life

This program has strong support from the sardine fishing industry in the study area, and the results will ensure that industry and resource managers have the best information possible.

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. A video describing the airborne component has been made by the Ocean Media Center of the NOAA Northwest Fisheries Science Center.

RELATED PROJECTS

This work is related to: 1) 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, 2) 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, 3) LIDAR surveys of menhaden done in September 2006 in Chesapeake Bay and the coastal Atlantic waters between the mouths of Chesapeake and Delaware Bays, and 4) an ONR LOCO project comparing ship based lidar with ship and moored acoustics, primarily focusing on plankton as targets.

PUBLICATIONS

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.

J. H. Churnside, J. Horne, P. Adam, R. D. Brodeur, D. Reese, E. Brown, K. J. Benoit-Bird, and A. Kaltenberg, "Combining techniques for remotely assessing pelagic nekton: getting the whole picture," American Institute of Fishery Research Biologist Symposium on The Future of Fishery Science in North America, Seattle, Washington, February 13-15, 2007.

P. M. Adam, J. K. Horne, and J. H. Churnside, "Unveiling time: using optics to quantify movement effects on acoustic abundance estimates," American Institute of Fishery Research Biologist Symposium on The Future of Fishery Science in North America, Seattle, Washington, February 13-15, 2007.

D. C. Reese, R. D. Brodeur, J. H. Churnside, and R. T. O'Malley, "Identifying spatial relationships between marine biological hotspots and fronts in the Northern California Current using remote-sensing techniques," ESA/SER Joint Meeting, San Jose, California, August 5-10, 2007.

D. C. Reese, R. D. Brodeur, J. H. Churnside, and R. T. O'Malley, "Using lidar and satellite imagery to identify the spatial relationship between nekton 'hotspot' areas and surface water conditions in the northern California Current," American Fisheries Society Annual Meeting, San Francisco, California, September 2-6, 2007.