

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 relationship 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

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 to analyze the array of spatial and temporal 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.

APPROACH

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.

In order to attain our objective of better understanding the connection between the ocean habitat and fish behavior, both for the purposes of interpreting data from various platforms as well as improving our knowledge of the ecological relationships influencing fish behavior, we have explored potential factors influencing the diel behaviors of sardine schools. The influence of prey abundance was investigated to determine what impact prey availability has on fish schooling behavior. This information will be used to more effectively interpret results from airborne lidar, ship and moored acoustics, and net sampling of fish communities.

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WORK COMPLETED

Analysis of the diel behavior of sardine schools has resulted in an extensive study of fish schooling behavior in the California Current System leading a manuscript that was recently submitted to *Marine Ecology Progress Series* entitled ‘The diel behaviors of sardine and anchovy schools in the California Current System.’ Data was combined with results from a related study that took place in Monterey Bay, California, investigating thin plankton layers using combined acoustics and airborne lidar. This has allowed us to do a comparative study on similar assemblages of schooling fish in response to different prey environments, leading to significance results based on differences observed in the two regions.

We have also explored potential approaches to integrate datasets from multiple platforms, including a data animation, to allow effective visualization of temporal and spatial patterns of school distributions. By combining the advantages of multiple platforms, we can obtain an improved perspective of sardine distribution and behavior. The advantages of this technique will include the;

- Spatial coverage from airborne lidar
- Vertical coverage from shipboard acoustics
- Temporal information from stationary moorings
- Species information from ship trawl surveys
- Identification of prey composition from ship plankton tows

This work has resulted in one published paper (Churnside et al., 2008), one currently in review (Kaltenberg and Benoit-Bird, in review) and several currently in the final stages of preparation for submission for review.

RESULTS

Diel schooling behavior

Fish schools were identified in shipboard and stationary acoustic datasets using the acoustic data analysis software, SonarData Echoview. Fish schools were distinguished from other biological features including zooplankton scattering layers, and individual fish (Figure 1). Each school was described by the time and date of occurrence, depth, length (from shipboard data), and duration (from mooring data). School lengths were corrected for acoustic beam geometry as described in (Diner 2001), and a similar method was used to correct school duration measurements from mooring data.

An analysis of variance analysis (ANOVA) of the 4 moorings deployed in 2006 revealed that there was no significant difference in the number of schools detected between the 4 mooring sites, located in the corners of 1 square nautical mile box pattern. However, a test for differences in the time of day that schools were detected concluded that schools were detected more frequently during the day than at nighttime (Figure 2). However, an opposite pattern of sardine schooling behavior was observed during sampling in Monterey Bay in 2005 and 2006, with schools detected both daytime and nighttime with the highest number of schools occurring at nighttime.

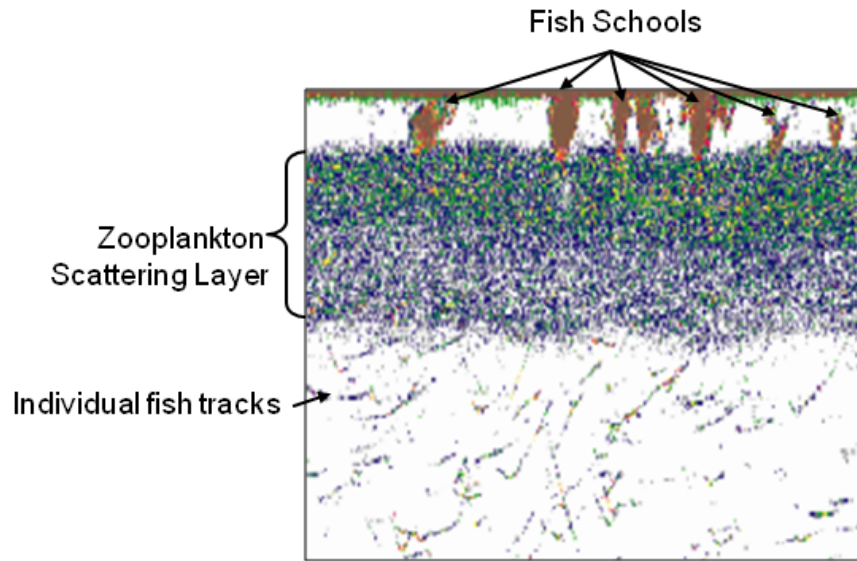


Figure 1. *Acoustic echogram from stationary WCP moorings deployed near Astoria, OR in 2005 and 2006.*

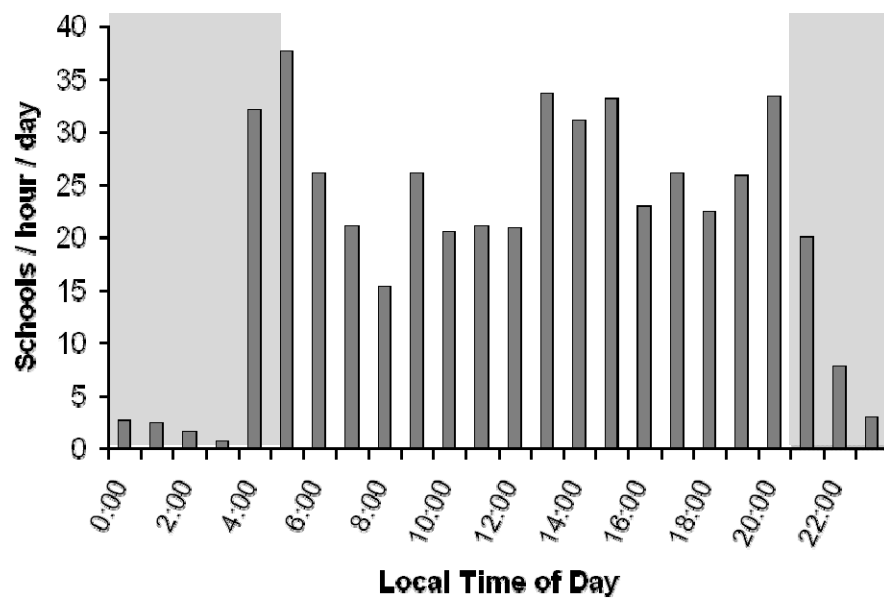


Figure 2. *The average number of schools detected by hour of the day. Most schools on the Oregon coast were detected during daytime hours and very few schools were observed at nighttime (shaded grey).*

The prey environment

A distinct vertical migration was apparent in stationary WCP mooring data (Figure 3). Zooplankton net tows indicated that there were relatively high concentrations of euphausiids at nighttime, which are strong diel vertical migrators. This pattern of diel vertical migration was consistently observed throughout the study.

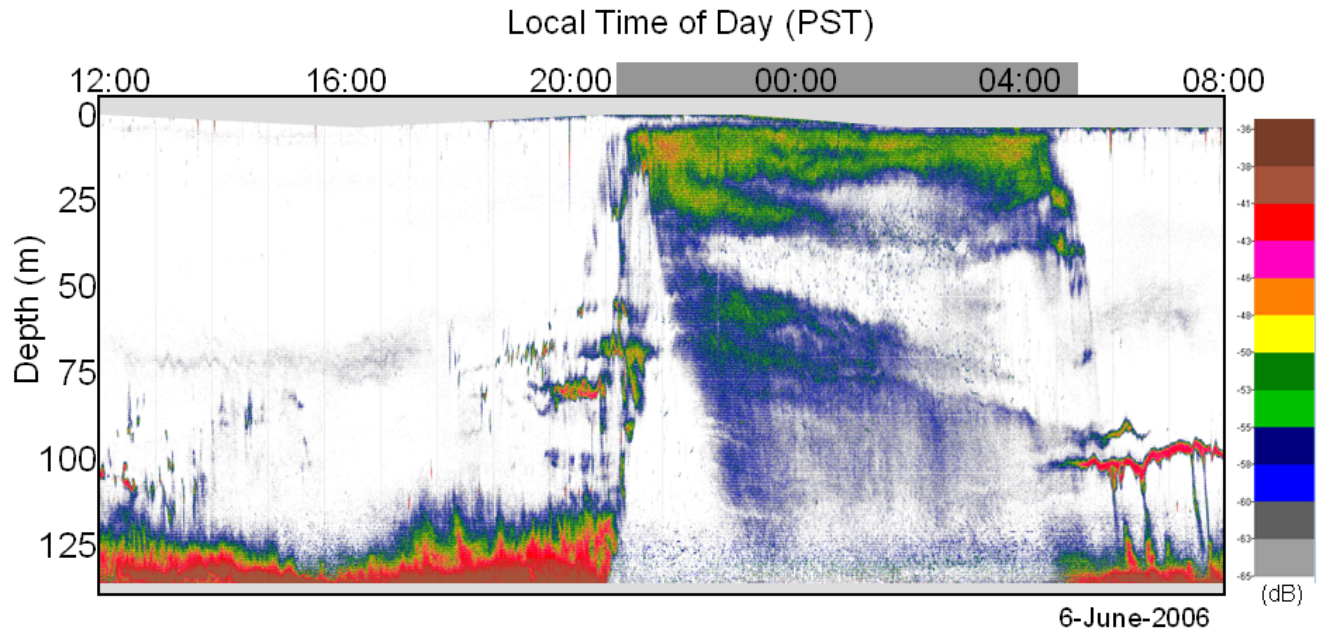


Figure 3. Acoustic echogram of backscatter collected from a WCP mooring in 2006. A diel vertical migration of zooplankton is visible migrating from near-bottom to the surface during nighttime.

Sardine schools, or single acoustic targets consistent with dispersed sardine individuals at nighttime were distributed throughout the water column both vertically and horizontally. So, to assess the total availability of plankton prey to foraging sardines, acoustic backscatter from stationary moorings was integrated from the surface to 1.5 m off the bottom (due to the height of the instrument). A strong diel pattern was consistently observed with highest prey availability during daytime and very low backscattering at nighttime, indicating very little prey available to fish predators during nighttime foraging hours (Figure 4). The opposite pattern of prey availability was observed in Monterey Bay, with the highest prey availability occurring at nighttime while fish were present in detectable schools. An important conclusion from this study was that sardines in the two regions appear to be behaving differently in response to the prey environment rather than simply to light levels, most likely related to balancing the amount of time fish spend in the anti-predator schooling behavior versus the dispersed behavior more effective for grazing.

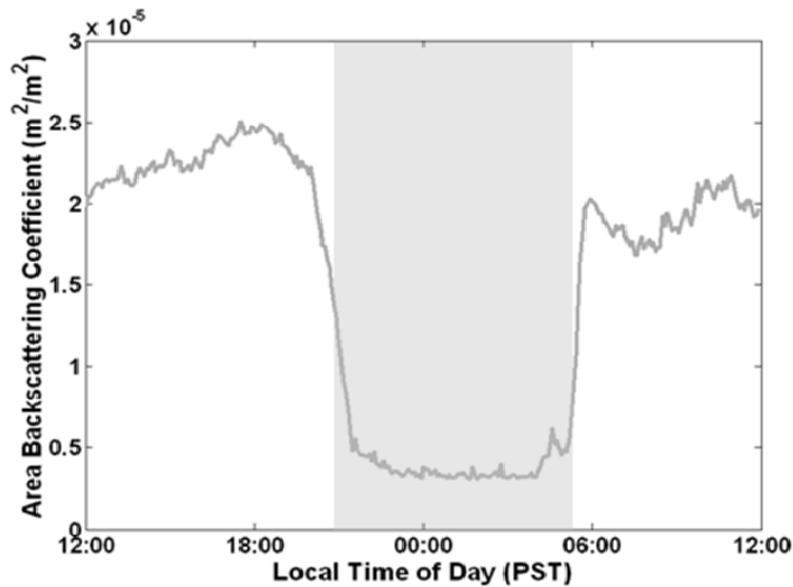


Figure 4. Acoustic backscatter index of prey availability. Prey availability off Oregon was highest during the day while sardines were in schooling behavior and low at nighttime, while fish were observed in dispersed behavior.

An integrated view of school distribution

Information resulting on the diel schooling behavior of sardines based primarily on acoustic techniques will be used to improve the integration of datasets from lidar, acoustics, and trawl surveys. There are several important conclusions on sardine schooling behavior that will improve techniques attempting to quantify their populations.

- Sardine schools on the Oregon/Washington shelf display a very strong diel pattern of behavior, likely in response to the availability of prey resources.
- Many daytime schools were associated with very near-surface waters, but a significant proportion of schools were also observed in deeper waters (beneath the range of airborne lidar).
- Schooling fish tended to disperse at nighttime both horizontally and vertically throughout the water column.
- Transitions of both zooplankton diel vertical migrations and schooling formation and dispersal at sunset and sunrise occurred rapidly and usually near sunset/sunrise (as opposed to other studies in which animals were observed ‘anticipating’ sunset or sunrise or responding to twilight light levels).

One of our approaches has been to visual sardine distribution as an animation of data collected from each individual platform (Figure 5). By animating the data, spatial the temporal patterns become apparent that are difficult to access by other methods. Further work will include applying statistical

methods to allow quantification of spatial and temporal patterns of sardine schooling behavior and spatial distributions relative to the oceanographic habitat.

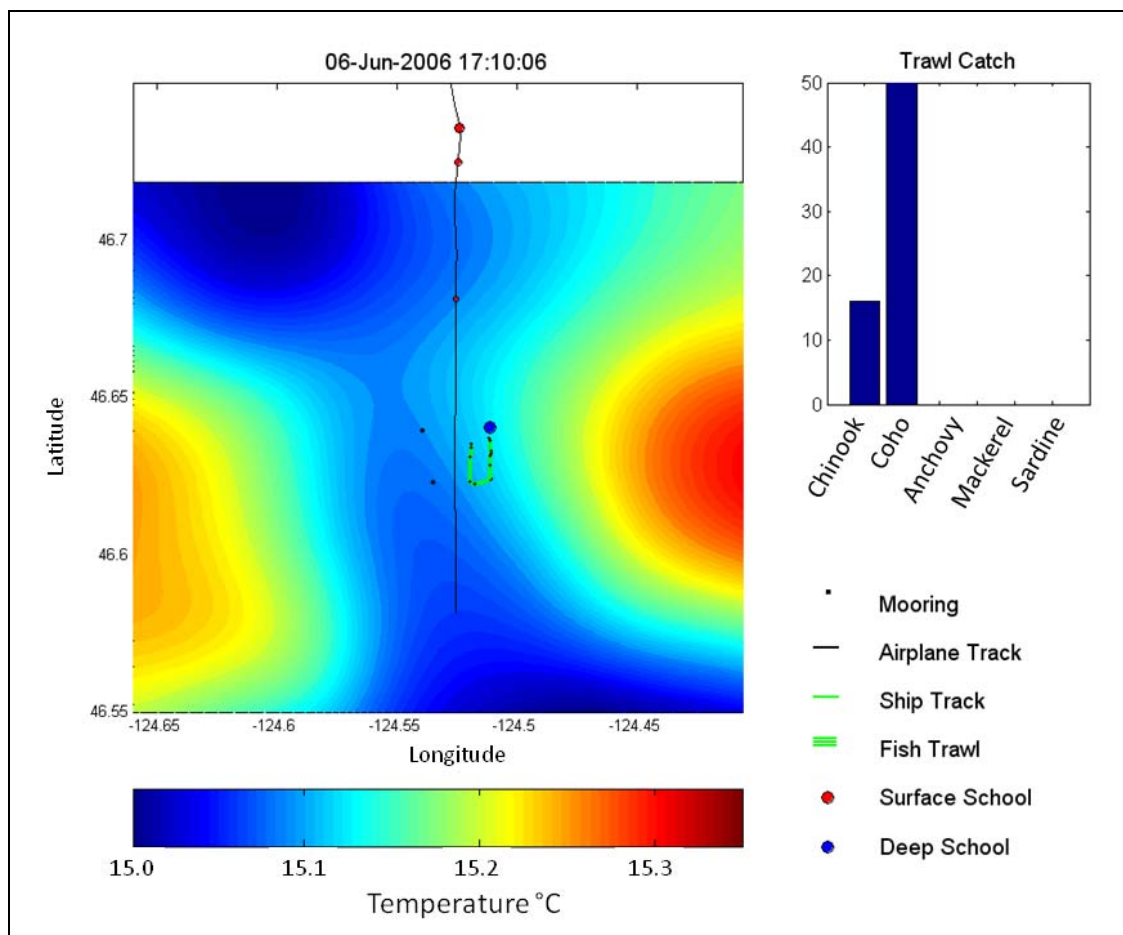


Figure 5. *An example image from the mapping animation integrating data from airplane, ship, and stationary moorings.*

IMPACT/APPLICATIONS

1. This project has resulted in a revised perspective of fish schooling behavior. Schools of sardines observed on the Oregon coast followed schooling behavior consistent with antipredator behavior of dispersing at nighttime and rapidly reforming into schools at nighttime. A comparison of the behavior of schools observed off Oregon with sardine schools in Monterey Bay, CA revealed that schools behaved quite differently and the diel behavior appears to be linked to prey availability.
2. We have shown that animations of data provide a unique perspective of data collection allowing us to visualize the temporal and spatial variability of sardine schooling behavior and distribution.

3. Combining our new perspective of diel schooling behavior with a full understanding of the limitations and advantage of multiple observational platforms will lead to increased accuracy of an index of fish abundance.

RELATED PROJECTS

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.

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PUBLICATIONS

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