



Secular Range Shifts of Fishes in the California Current Ecosystem Over Seven Decades?

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Introduction

Understanding how fish distributions shift through space and time is important for fisheries management. To provide the best possible information to inform management, it might be helpful to track patterns of movement of fishes over time and space, within and between countries that share fish species.

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) program has been monitoring larval fish abundances within the California Current Ecosystem (CCE) since 1949. From 1949-1984, CalCOFI sampled from the California/Oregon border south to Cabo San Lucas. From 1984-present, CalCOFI largely focused on locations between San Francisco the US/Mexico border and samples were not collected in the southern CCE. Fortunately, the Investigaciones Mexicanas de la Corriente de California (IMECOCAL) program reoccupied the southern CalCOFI stations from 1998-2016.

We combine CalCOFI and IMECOCAL ichthyoplankton data in an attempt to provide insight on whether the distribution and abundance of fishes throughout the CCE have changed over almost six decades.

Here, we ask the following questions:

- 1) Have fish centers of gravity (COG) shifted north?
- 2) If fish COG changed, does adult habitat (benthic vs. pelagic) and biogeographic range (e.g., north or south relative to the US/Mexico border) impact movement?
- 3) If fish systematically moved, how far have they gone?

Methods

CalCOFI and IMECOCAL collect plankton with obliquely towed nets that are dropped in the sea to 210 m or within 10 m of the bottom at shallow stations (Fig 1). In the laboratory larval fishes (ichthyoplankton) are sorted and identified to the lowest taxonomic level (usually species) by amazing experts like Bill Watson.

The sample frame of CalCOFI and IMECOCAL has shifted over the years. Here, we concentrate on locations that that were most consistently sampled: an ~1100 km stretch between just north of Point Conception, CA (CalCOFI line 76.7) and just south of Punta Eugenia, Baja California Sur (line 127.0) (Fig. 2). We include in our analysis one survey per year from winter, spring, summer and fall.

The combined CalCOFI/IMECOCAL data includes over 700 fish taxa. To ensure that taxa were unambiguously defined in both programs through time, we filtered taxonomic designations. For example, we eliminated rockfishes identified to genus (*Sebastes* spp.) as we could not discern if the same or different species were identified in the US vs. Mexico. In addition, some CalCOFI species were identified to higher taxonomic levels prior to 1960 (e.g., to family or genus rather than species), so we restricted analysis to 1960-2016.

We hypothesized that adult habitat (benthic vs. pelagic) or geographic range (north or south of the US/Mexico border, centered on the Southern California Bight (SCB) or cosmopolitan (spread throughout the region) could impact shifts in COG. We thus classified habitat and range for each taxa based upon expert knowledge (Bill Watson and Hsieh et al. 2005. Prog. Ocean 67:160-85).

To discern if distributions shifted over time, we calculated abundance-weighted center of gravity (COG) for each taxa. We then used simple linear models to regress COG ~ year in each season. We limited our analysis to taxa that were found in at least 15 season/years. This eliminated many rare taxa and left us with 128 for this poster.

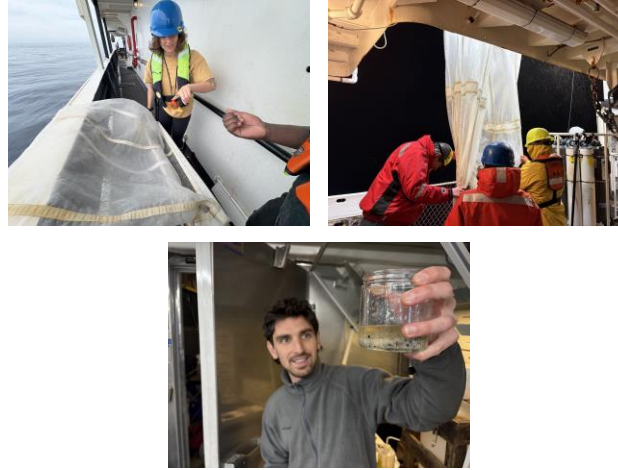


Fig. 1. Plankton sampling at sea with Jenna and Nico

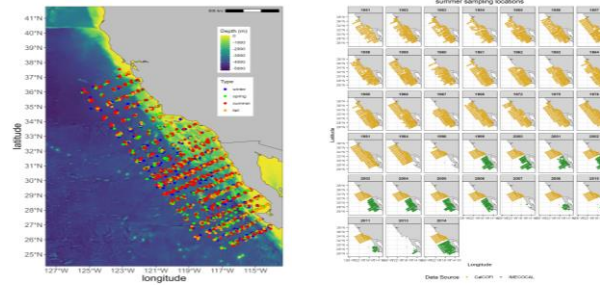


Fig. 2. Many of the locations sampled by the CalCOFI (gold) and IMECOCAL (emerald) programs

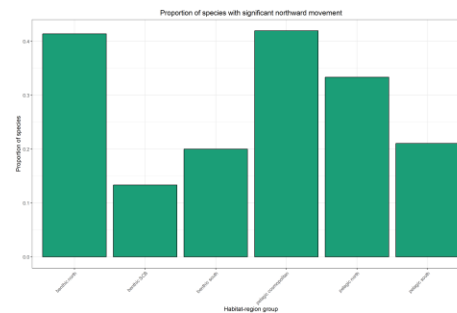


Fig. 3. Proportion of fishes within categories of a adult habitat and geographic range who's Center of Gravity moved north.

Results

Depending on a adult habitat and geographic distribution, the Center of Gravity (COG) of between 12 and 41% of species significantly shifted northwards in at least one season (Fig. 3,4) between Pt. Conception and Punta Eugenia from 1960-2016. COG shifted more frequently for taxa with northern and cosmopolitan geographic ranges than those with southern ranges, but there was no apparent difference between pelagic and benthic taxa (Fig. 3).

For taxa that changed COG, the median shift was between ~200 and ~500 km north (Fig. 5)



Fig. 4. Example of significant relationships between year and COG for one group of fishes

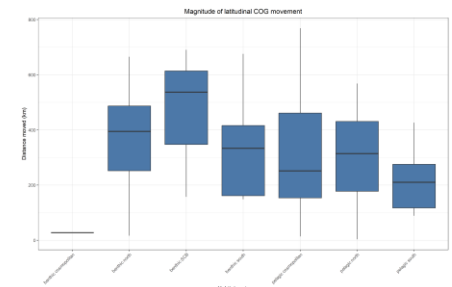


Fig. 5. Box plot of distance of latitudinal movement for species that changed COG

Discussion/Future Research

We are fortunate to be part of the best fisheries monitoring program in the world.

Collaboration between US and Mexican scientists has made this research possible.

This poster is hopefully the **beginning**. Future questions that we can answer include, but are not limited to:

1. How has ocean temperature and other physical oceanography parameters affected these pattern?
2. Has inertia, leading and trailing edges of distribution changed?
3. Have patterns of species richness and biogeographical barriers changed?
4. Can more sophisticated analysis tools (e.g., VAST) and additional expert analyses improve our capacity to optimally manage fish?