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A comparison of long-term trends and variability in populations of larvae of exploited and unexploited fishes in the Southern California region: A community approach

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Abstract

We have constructed an "expert-knowledge classification system" to categorize 309 fish taxa in the California Cooperative Oceanic Fisheries Investigations ichthyoplankton database into primary (coastal, coastal-oceanic, and oceanic) assemblages based on their principal ecological domains and subsequently, secondary assemblages according to the habitat affinities of adults. We examined effects of fishing, climate, adult habitat, and age-at-maturation on long-term variation of fish populations. We tested the hypothesis that populations of unexploited taxa track climatic trends more closely than those of exploited taxa insofar as climatic signals may be confounded by fishing effects.

Most oceanic taxa (23/34) showed a significant relationship with environmental variables and followed the trend of the Pacific Decadal Oscillation. Very few coastal (3/10) and coastal-oceanic (3/23) taxa exhibited a significant relationship with environmental signals; however, several fluctuated coherently, and age-at-maturation is an important factor. The lack of close correlation between fish populations and environmental signals in the coastal and coastal-oceanic assemblages indicates that these species might show nonlinear biological responses to external forcing rather than a simple linear tracking of environmental variables.

We did not find a systematic pattern indicating that fishing influenced population fluctuation of exploited species. Constrained comparisons of exploited to unexploited species living in the same habitat and reaching maturity at the same age revealed evidence of overexploitation for some species but not for all. Our results suggest that considering

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life history and ecological characteristics of fish species and applying a community approach are important in understanding fishing effects on fish populations in the context of a changing environment.

Keywords: Fish assemblages; CalCOFI time series; Fishing effects; Climate; Age-at-maturation

1. Introduction

Understanding decadal-scale climatic effects on the Northeast Pacific marine ecosystem is an important issue because strong environmental changes have occurred at this time scale (Chavez, Ryan, Lluch-Cota, & Niquen, 2003; Hare & Mantua, 2000; McGowan, Bograd, Lynn, & Miller, 2003; Venrick, McGowan, Cayan, & Hayward, 1987). It has been hypothesized that a regime or an ocean climate condition may persist for 2–3 decades and then undergo a rapid change to another state (Mantua, Hare, Zhang, Wallace, & Francis, 1997; Trenberth & Hurrel, 1994). However, whether these changes are regime shifts generated from underlying nonlinear dynamics or manifestations of red noise is still debated (Pierce, 2001; Rudnick & Davis, 2003). Evidence of warming in the North Pacific since 1976 and a variety of biological responses have been noted (Beamish, Neville, & Cass, 1997; Brinton & Townsend, 2003; Lavaniegos & Ohman, 2003; Roemmich & McGowan, 1995a, 1995b). Cool conditions in the North Pacific continuing after 1998 suggest another transition to a new ocean state (Ohman & Venrick, 2003; Peterson & Schwing, 2003). In addition to these low-frequency effects, biological production is affected by high-frequency El Niño/Southern Oscillation events (Fiedler, Methot, & Hewitt, 1986; Yoklavich, Loeb, Nishimoto, & Daly, 1996).

Clearly, fluctuations of exploited fish populations can be affected by both environmental forcing and fishing mortality (Jacobson et al., 2001; McFarlane, Smith, Baumgartner, & Hunter, 2002), and these factors are inextricably convolved in catch data. From the viewpoints of fisheries management and conservation of marine resources, it is important to determine fishing effects on fish populations and communities within the context of a changing environment. This view is an essential component of ecosystem-based approaches to fisheries management that has gradually become the standard requirement for fisheries management; that is, to base management decisions not only on the status of a fish population but also the ecosystem (Browman & Stergiou, 2004; Garcia, Zerbi, Aliaume, Do Chi, & Lasserre, 2003; NOAA, 1999; Pikitch et al., 2004). One practical issue here is to develop approaches that can be used to separate fishing from environmental effects on fish populations. Analyses of long-term data on the abundance of species taken independently of their fishery offer the best chance to achieve this goal. The larval fish data collected in the California Cooperative Oceanic Fisheries Investigations (CalCOFI) may be useful to separate these effects, because the CalCOFI program is one of the most comprehensive observational oceanography programs in the world and spans more than 50 years (Hewitt, 1988; Ohman & Venrick, 2003).

Larval abundances are primarily measures of the spawning biomass and reproductive effort of the adult stock for the year, because most larvae taken in plankton nets are in a very early stage of development. However, their abundance is not correlated with subsequent year class strength (Peterman, Bradford, Lo, & Methot, 1988). Long-term trends in larval abundance mostly reflect trends in adult biomass; short-term fluctuations are likely related to episodes of high or low reproductive output or geographic shifts due to animal movement (e.g., El Niño effects), since sudden changes in biomass would not be expected (Moser et al., 2000). Several studies have shown that larval abundance is a good indicator of adult biomass (Gunderson, 1993; Moser et al., 2000; Moser et al., 2001b; Moser & Watson, 1990). The common use of larval indices in stock assessment models also supports this conclusion. Given that there are no long-term