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Mortalities of kelp-forest fishes associated with large oceanic waves off central California, 1982–1983

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Synopsis

Observations of three incidents of the mass mortality of nearshore fishes are reported; each corresponded to periods of high-amplitude, long-period swells during the 1982–1983 El Niño event along the coast of central California. Members of the nearshore kelp forest fish assemblage, primarily of the genus *Sebastes*, accounted for 96% of the observed mortalities and *S. mystinus* (blue rockfish) alone accounted for 72%.

Introduction

The El Niño of 1982–1983 was among the strongest of the century (Cane 1983). Along the California coast, this event was manifested as two distinct physical phenomena. First, severe storms and unusually high-amplitude, long-period waves were frequent from late November 1982 through mid March 1983 (Seymour et al. 1983, 1984a, b, Earle et al. 1984). Second, normal upwelling during spring 1983 was much reduced in intensity relative to normal years, and relatively warm, oligotrophic water masses moved in from the south, dominating the coastal marine climate into 1984 (Fiedler 1984).

During previous El Niño events in California, interest in affected fish assemblages has focused on the impact of thermal anomalies in coastal waters. The appearance of typically low-latitude species off California has been correlated with the northward movements of relatively warm water masses (e.g. Hubbs & Schultz 1929, Walford 1931, Radovich 1960, 1961). To our knowledge, there is but one account (Follett 1970) of nearshore fish mortalities directly associated with extreme wave events in California. No published accounts specifically detail mortalities of kelp-forest fishes as a result of large coastal waves in California.

Methods

From February 1980 to January 1986 we systematically surveyed all beaches between Pt. Sierra Nevada (35° 43′ N, 121° 19′ W), and Pt. San Simeon (35° 38′ N, 121° 12′ W), California, a shoreline distance of 16 km. Surveys were made monthly with the primary intention of monitoring mortalities of coastal marine mammals and birds, as indicated by the appearance of beachcast carcasses. Before January 1983, strandings of fish were so rare that quantitative records were not kept. From January 1983 to January 1986, however, all beachcast fish within the study area were recorded.

Results

We found beachcast kelp-forest fishes in the study area on three occasions in 1983, during beach surveys following extreme wave events on 25–27 January, 10 February, and 28 February–2 March (Table 1). The January and March events included sea and swell to a combined height of 8–10 m, peak local winds of 80–120 km h^{-1}, rainfall rates to 50 mm day^{-1}, and heavy runoff of turbid water from coastal streams (Seymour et al. 1984a, b, Earle et al. 1984, National Weather Service, unpublished observations, U.S. Fish and Wildlife Service, unpublished observations). Combined effects of runoff and severe wave surge caused unusually high turbidity in nearshore waters along the study area (U.S. Fish and Wildlife Service, unpublished observations). The February event lacked high winds and heavy rain, but included extreme high-amplitude, long-period swell states (Seymour et al. 1984a, b, Earle et al. 1984). Most fish found during beach surveys were moribund or recently dead and were near the high water mark on beaches. During additional casual observations within the study area on 10 February, we found several blue rockfish, *Sebastes mystinus*, together with wrack, beach sand, and sea foam, on the paved surface of State Highway 1, 50 m inshore from the mean high water mark, in an area inundated by breaking waves during a previous high tide.

We measured standard lengths of 26 beachcast *S. mystinus*, as encountered, during the February and March events ($\bar{x}$ = 283 mm, range = 232–322 mm). This mean did not differ significantly (two sample

Table 1. Numbers of beachcast fish found in study area during extreme wave events, winter 1983, and densities of beachcast species in kelp forests adjacent to study area, 1982–1983.

Species	Habitat[a]	Date[b]			Total beachcast fish	Estimated mean densities (n ha^{-1}) of fish in adjacent kelp forests (from Bodkin 1984 and Bodkin unpublished data)	
		25–27 Jan.	10 Feb.	28 Feb.–2 Mar.		1982	1983
Scorpaenidae							
Sebastes mystinus	M	43	17	42	102	1490*	484
Sebastes carnatus	D, R	1	6	5	12	110*	47
Sebastes chrysomelas	D, R	2	3	8	13	137*	205
Sebastes miniatus	D, R	2	0	1	3	10	4
unidentified *Sebastes* spp.		0	0	3	3	–	–
Sebastes serranoides	M	0	0	2	2	39	20
Stichaeidae							
Cebidichthys violaceus	D, R	0	0	2	2	–	–
Embiotocidae							
Phanerodon furcatus	M	0	1	0	1	0	70
Pleuronectidae							
Platichthys stellatus	D, S	0	0	1	1	–	–
Hexagrammidae							
Ophiodon elongatus	D, R, S	1	0	0	1	13	9
Ophidiidae							
Brosmophycis marginata	D, R	1	0	0	1	–	–
Total		50	27	64	141		

[a] Abbreviations: D = demersal; M = midwater; R = rocky; S = soft bottom.

[b] Based on beach surveys of 27 January–2 February 1983, when 60% (9.6 km) of the study area was surveyed; 10 February 1983, when 4% (0.6 km) of the study area was surveyed; 3–7 March 1983, when all of the study area was surveyed.

* Difference significant between years ($P<0.05$; two-sample t-test)

t-test) from a sample of 86 *S. mystinus* captured and measured in 1982 and 1983 in nearshore kelp beds directly offshore from the study area ($\bar{x}$ = 252 mm; range = 138–330 mm).

From March 1983 to January 1986, only four beachcast fish were found within this study area: three *Cebidichthys violaceus* (monkeyface prickleback) and one unidentified *Sebastes* (rockfish).

Discussion

Bodkin (1984) estimated densities of fishes in kelp forests adjacent to the study area during summer and fall in 1982 and 1983, using visual counts along 78 transect lines during scuba dives. Strandings of fish during winter 1983 occurred approximately in proportion to patterns of abundance in the fish assemblage of the adjacent kelp forests (Table 1).

Follett (1970) observed fish strandings after an extreme wave event at Pt. Joe (36° 37′ N, 121° 58′ W), California in February 1960. Waves were comparable in size to those observed in 1983 (Seymour et al. 1984a). Although kelp-forest habitat is extensive near Pt. Joe (U.S. Fish and Wildlife Service, unpublished data), stranded fish observed during the 1960 event were not typical of kelp-forest assemblages, and many of the species stranded are generally associated with other habitat types (e.g. *Sebastes helvomaculatus* and *Chilara taylori* are typically found on sandy substrata in deeper water). We have no explanation for the difference between Follett's data and our own.

Densities of *S. mystinus*, the dominant species in numbers and biomass, declined significantly (by 68%) in kelp forests adjacent to the study area between 1982 and 1983 (Bodkin 1984, Table 1). Direct mortality associated with large waves probably contributed to the decline, although the number of beachcast fish found clearly was insufficient to account for the decline. Loss of kelp-forest habitat resulting from extreme waves, redistribution of fish to other habitat types, or stress associated with anomalously warm water during summer 1983 may have added to the decline. Stephens et al. (1984) documented a decline in nearshore rockfish densities, primarily *S. mystinus* and *S. serranoides* following a widespread warming of water temperatures in the southern California bight. These changes appeared to be more gradual, occurring over a period of several years beginning in 1977. It is also possible, although in our view unlikely, that changes in density of blue rockfish were not related to the El Niño event.

The mechanisms by which large waves kill nearshore marine fishes remain unknown. One obvious possibility is that individual fish are simply flung from the sea by wave-associated forces exceeding the capacity of the fish to maintain their positions. Other storm-associated factors, such as increased turbidity or reduced salinity, may contribute to diminished physical capacity, either by direct physiological impact or by reducing prey availability or foraging efficiency. Robins (1957) observed severe gill erosion by accumulated sediments in many beachcast fish following a severe storm near Miami, Florida. During the final stages of a tropical cyclone Lassig (1983) noted a large number of fish with fresh wounds, likely caused by abrasion with the substrate. In the present study we were unable to evaluate the condition of beachcast fish at the time they were tossed ashore; thus we are unable to speculate soundly about the possible mechanisms of mortality. However, extreme wave height with associated turbidity and period were the only two factors present during each of the three episodes that produced fish strandings.

The observations presented here, in conjunction with evidence presented by others (Robins 1957, Follett 1970, Lassig 1983) suggest that physical disturbances caused by extreme wave and wind events, although they may be rare, may have substantial effects in both temperate and tropical nearshore marine fish communities.

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