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MOVEMENT OF SCORPIONFISHES (SCORPAENIDAE: *SEBASTES* AND *SCORPAENA*) IN THE SOUTHERN CALIFORNIA BIGHT [1]

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The movement of 25 species of rockfishes and three incidentally-taken species was studied to provide information necessary for management of this nearshore resource. Results of a tag-and-release program indicate that most of the species studied are sedentary or make only small scale (<10 km) movements. The bocaccio, *Sebastes paucispinis,* and olive rockfish, *S. serranoides,* were the only rockfishes for which large scale (>10 km) movement was documented. Bocaccio were noted to move up to 148 km.

Movement of up to 218 km was demonstrated for the California scorpionfish, *Scorpaena guttata.* Tag return and other data are presented which suggest that California scorpionfish, once thought to be sedentary, move freely through midwater and travel long distances, presumably to spawn.

INTRODUCTION

In California, the scorpionfish family (Scorpaenidae) is comprised of 66 species, including 62 rockfishes *(Sebastes)* (Hubbs, Follett and Dempster 1979). Scorpionfishes support both commercial and sport fisheries and are becoming increasingly important in each. From 1973–1977, the average annual California scorpionfish catch (combined sport and commercial) was nearly 15,000 MT. By 1982, this figure had increased to nearly 35,000 MT.

Because many aspects of rockfish life history and population dynamics are poorly or incompletely understood, additional information must be collected before a sound management plan can be developed. Knowledge of rockfish movement is one area in need of more research. Most existing studies of rockfish movement were conducted in waters north of Point Conception, and may not apply to southern California stocks.

Management strategies for species which move freely over long distances will differ from strategies employed to manage species which inhabit only limited areas throughout their life histories. If recruitment to a given reef system is solely from the adults inhabiting that sytem and the adults are sedentary, then management must be on a system by system basis. However, if recruitment to a given reef system does not depend solely on the adults inhabiting that system, or if adults move freely between reef systems, then management over a wider area is necessary. Because scorpaenids have pelagic larvae which are widely dispersed by currents (Ahlstrom 1961) recruitment may be closely correlated to the adult populations of continguous systems upcurrent.

A recent summary of published observations on movements of rockfishes in the eastern north Pacific indicates that most shallow-water (<70 m) species are sedentary and undertake only small-scale (<10 km) movements (Love 1980).

[1] Accepted for publication January 1986. This work was performed as part of Dingell Johnson project F-32-R, "Southern California Marine Sportfish Research Program", supported by Federal Aid to Fish Restoration funds.

[2] A. Rucker Hartmann drowned on 9 October 1984 while at sea.

The black rockfish is a notable exception, with documented movements up to 619 km. More recently, large-scale movements (> 10 km) over 50 km have been recorded for brown rockfish (William Lenarz, Nat. Mar. Fish. Serv., pers. commun.) and up to 157 km for yellowtail rockfish (Robert N. Lea, Dept. Fish and Game, pers. commun.). For purposes of this discussion, movements less than 10 km will be denoted as small-scale; those greater than 10 km will be considered large-scale.

Indirect evidence indicates that some deepwater (> 70 m) rockfishes such as bocaccio, *S. paucispinis;* chilipepper, *S. goodei;* widow rockfish, *S. entomelas;* cowcod, *S. levis;* and vermilion rockfish, *S. miniatus* may move about extensively. This evidence includes large, temporal changes in catch-per-unit effort at regularly fished spots and fathometer tracking of rockfish aggregations over substantial distances in short periods of time (Love 1981).

Some species such as chilipepper, bocaccio, and shortbelly rockfish, *S. jordani,* have morphological characteristics suggesting adaptations for swimming continuously in the water column. These characteristics include fusiform body, narrow caudal peduncle, and deeply incised dorsal fin (Adams 1968).

Differences in the depth distribution of juveniles and adults indicate that movement from shallow, nearshore habitat to deeper, offshore waters may be a function of age for some rockfish species. Gascon and Miller (1981) found that only rockfishes 6–15 cm in length colonized shallow (5–10 m), nearshore artificial reefs in Barkley Sound, British Columbia. Larger individuals were presumed to have moved into deeper water, but neither the extent nor the timing of such movements was investigated.

To add to the existing knowledge of rockfish movement, the California Department of Fish and Game conducted a tag-and-release program in the Southern California Bight from 1977–1980. The rockfish tagging program also provided an opportunity to tag incidentally-taken species including California scorpionfish, *Scorpaena guttata;* lingcod, *Ophiodon elongatus;* and cabezon, *Scorpaenichthys marmoratus.*

Large, intermittent concentrations of California scorpionfish are known to occur in certain areas of high bottom relief during the spring and summer, coincident with the spawning season. The sudden appearance and disappearance of these aggregations, which generally last for several weeks or months, suggests movement (Taylor 1963). Spring and summer aggregations of California scorpionfish were also noted by Turner et al. (1969) who attributed them to spawning migrations from shallow, inshore reefs to deeper, offshore banks.

MATERIALS AND METHODS

Rockfishes and some associated species were tagged and released during a series of 11 research cruises conducted from 1977 to 1981 between Point Conception and the Mexican border, and around the offshore banks and islands of the Southern California Bight. (Figure 1). Additional fishes were tagged near the Los Angeles-Long Beach Breakwater complex (hereinafter designated L.A. Breakwater).

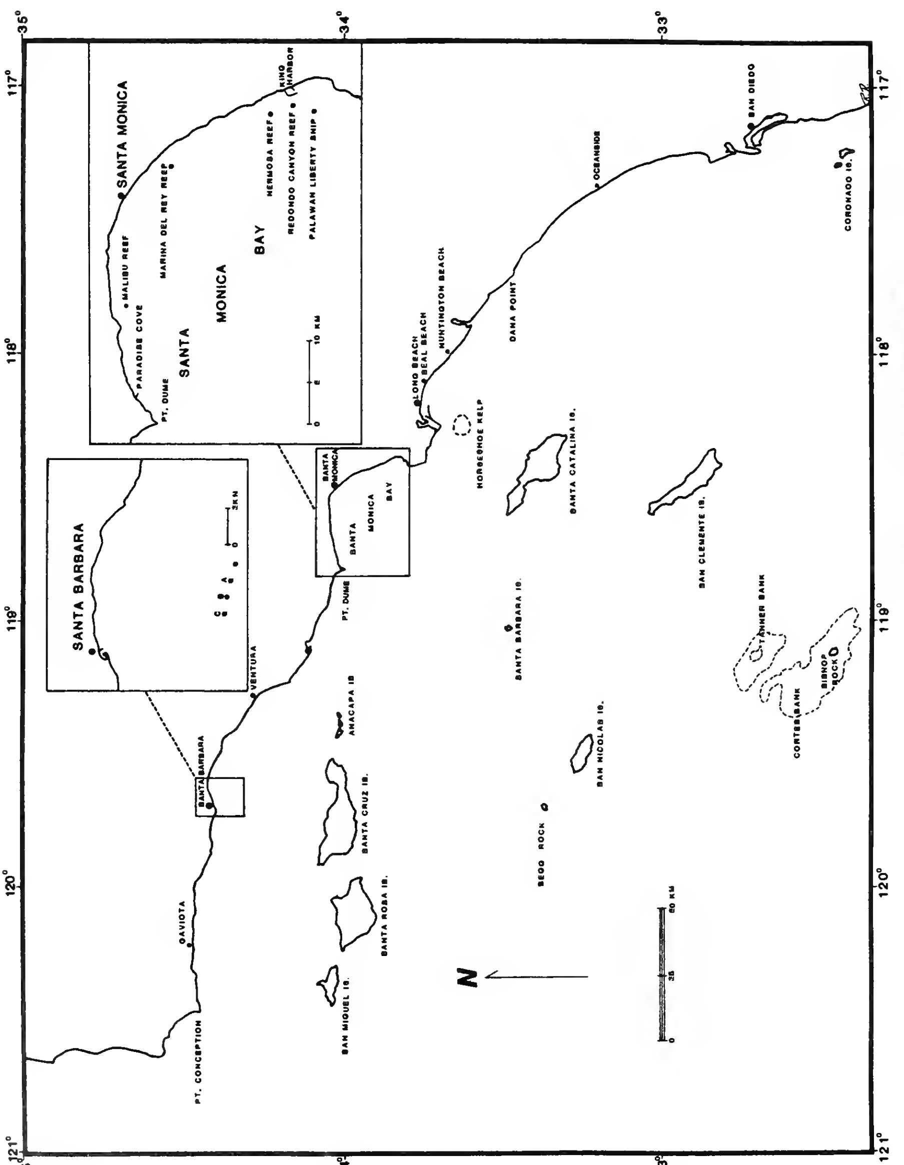

FIGURE 1. Location of rockfish tagging and recapture sites in the Southern California Bight.

Capture sites were generally shallow water areas, less than 70 m in depth. Specimens were captured with hook-and-line using a variety of natural and artificial baits. Specimens were identified, measured to the nearest mm total length, tagged, and released at the site of capture. Individuals exhibiting signs of excessive gas expansion in the swim bladder (everted stomachs) or in the choroid plexa (everted eyes) were not used.

Fishes showing only signs of moderate gas expansion (inflated appearance) were deflated prior to tagging using the technique devised by Gotshall (1964) and modified by Love (1980).

Serially numbered Floy FD68B anchor tags, bearing the legend "Reward. Calif. Fish & Game, Long Beach", were inserted into the epaxial musculature under the dorsal fin with a Floy FDM-68 tagging gun.

Posters describing the tagging program, information to be included with tag returns, and reward were conspicuously posted at sport landings from San Diego to Santa Barbara. Anglers who returned tags received a reward of $2.00 per tag and a commendation card. When possible, follow-up contacts were made to verify or supplement the information obtained from the fishermen.

The data on California scorpionfish movement collected during this study were supplemented with information from an earlier study conducted from May 1972 through May 1975 in the Southern California Bight. In the 1972–1975 study, California scorpionfish were captured underwater by divers using hand-held nets, placed in a holding cage, and tagged on shipboard using a method similar to that described above. Scorpionfish data from the Department of Fish and Game's midwater trawl surveys, commercial landing records, and gill net logs were also considered.

RESULTS

Of 10,658 fishes tagged, including 25 species of rockfishes, California scorpionfish, lingcod, and cabezon, 697 (7%) were recaptured by 14 December 1983. Recapture rates were extremely variable between species, ranging from none for a number of species to 21% for brown rockfish (Table 1). Comparing release sites, recaptures ranged from 1.5% for Cortes Bank to 59% for the Redondo Canyon Artificial Reef (Table 2). Periods at liberty varied from 1 to 1,775 days.

Six hundred-and-six fishes were recaptured at their sites of tagging. Movement was shown by 89 individuals comprising six species (Table 3). Of this number, only 12 fishes, of 4 species, moved distances greater than 10 km (Table 4). Although movement was documented for some individuals of these six species, other individuals were recaptured at their tagging sites after extended periods at liberty (Table 5).

Fishes Showing Movement

Olive rockfish

Olive rockfish inhabiting isolated reefs were studied by Love (1980) who found that movement was restricted in shallow water, presumably limited by stretches of sandy bottom lacking the high relief substrate with which this species is generally associated. In deeper water, however, olive rockfish traversed short distances of up to 0.8 km. Love speculated that movement of greater magnitude

TABLE 1. Number and Percentage of Fishes Tagged and Recaptured.

Common name	*Scientific name*	*Total number tagged*	*Total number recaptured*	*Percentage recaptured*
Black rockfish	*Sebastes malanops*	1	0	0
Black-and-yellow rockfish	*S. chrysomelas*	57	11	1.8
Blue rockfish	*S. mystinus*	2,402	98	4.1
Bocaccio	*S. paucispinis*	1,149	66	5.7
Brown rockfish	*S. auriculatus*	76	16	21.1
Calico rockfish	*S. dalli*	27	0	0
Canary rockfish	*S. pinniger*	13	0	0
China rockfish	*S. nebulosus*	4	0	0
Copper rockfish	*S. caurinus*	409	16	3.9
Flag rockfish	*S. rubrivinctus*	3	0	0
Gopher rockfish	*S. carnatus*	83	8	9.6
Grass rockfish	*S. rastrelliger*	20	2	10.0
Greenspot rockfish	*S. chlorostictus*	1	0	0
Honeycomb rockfish	*S. umbrosus*	11	0	0
Kelp rockfish	*S. atrovirens*	515	8	1.4
Olive rockfish	*S. serranoides*	4,085	435	10.6
Rosy rockfish	*S. rosaceus*	17	0	0
Speckled rockfish	*S. ovalis*	5	0	0
Squarespot rockfish	*S. hopkinsi*	103	0	0
Starry rockfish	*S. constellatus*	24	3	12.5
Treefish rockfish	*S. serriceps*	7	1	14.3
Vermilion rockfish	*S. miniatus*	160	6	3.8
Widow rockfish	*S. entomelas*	1,146	17	1.5
Yelloweye rockfish	*S. ruberrimus*	2	0	0
Yellowtail rockfish	*S. flavidus*	54	1	1.9
Cabezon	*Scorpaenichthys elongatus*	41	0	0
Lingcod	*Ophiodon elongatus*	135	7	5.2
California scorpionfish	*Scorpaena guttata*	108	10	9.3
TOTAL		10,658	697	6.5

might occur in areas providing long, continuous stretches of cover such as that provided by kelp beds.

Of the 61 olive rockfish movements observed during this study, 58 were small-scale. In Santa Monica Bay, offshore from Santa Barbara, and along the L.A. Breakwater, olive rockfish, at liberty from 8–484 days, covered distances of 0.7 to 7.0 km. Only three individuals moved distances greater than 10 km (Tables 3 & 4). Of these, 2 olive rockfish tagged in Santa Monica Bay were recaptured after moving around the Palos Verdes Peninsula, 12 and 33 km respectively, through an area of nearly continuous kelp forest. This tends to support Love's (1980) hypothesis regarding movement of olive rockfish in areas of continuous cover. The third olive rockfish, tagged at the L.A. Breakwater, moved 18 km to a point offshore. Since bottom conditions are variable in this area, it is impossible to determine what bottom type occurred along the path of this fish. It is certain, however, that continuous kelp canopy did not exist here.

Blue rockfish

Blue rockfish in central California were studied by Miller and Geibel (1973) who found that movement in and between kelp beds was restricted. In deeper reef areas, wandering movements up to 1.3 km were common, but few fish moved farther than 10 km. The longest movement recorded in their study was 24 km. During this study, only eight of 98 blue rockfish recaptured exhibited movement. A total of seven individuals traveled distances ranging from 1.0 to 7.0 km along the L.A. Breakwater after 20 to 468 days (Table 3). One blue rockfish, at liberty for 767 days, moved 43 km from Santa Rosa Island to San Miguel Island. This fish had to cross the San Miguel Passage, a channel with a minimum depth of 26 m (Table 4).

TABLE 2. Number and Percentage of Fishes Tagged and Recaptured in Various Areas.

	No. fishes released	*No. fishes recaptured*	*Percentage recaptured*
Santa Barbara County nearshore			
Oil Platforms	2,471	96	3.9
Other nearshore	1,300	127	9.8
TOTAL	3,771	223	5.9
Santa Monica Bay			
Hermosa Artificial Reef	411	67	16.3
Redondo Canyon Artificial Reef	200	117	58.5
Palawan Liberty Ship	1,034	141	13.6
Marina del Rey Artificial Reef	53	12	22.6
Other nearshore	5	–	–
TOTAL	1,703	337	19.8
Los Angeles to San Diego County Coastal			
Los Angeles Breakwater	391	40	10.2
Los Angeles County	11	–	–
Orange County	2	–	–
San Diego County	103	5	4.9
TOTAL	507	45	8.9
Offshore Islands			
Santa Cruz Island	75	3	4.0
Santa Rosa Island	1,634	67	4.1
San Miguel Island	2,066	5	2.4
Santa Catalina Island	45	–	–
Santa Barbara Island	43	–	–
San Clemente Island	486	10	2.1
TOTAL	4,349	85	2.0
Offshore Banks			
Tanner Bank	54	1	1.9
Cortes Bank	274	4	1.5
TOTAL	328	5	1.5

TABLE 3. Number of Tagged Fishes Which Exhibited Movement.

	Minimum distance moved (Km)						
Species	*<1*	*1–2*	*2–5*	*5–10*	*>10*	*TOTAL*	*Percentage of total returns*
Olive rockfish	7	36	9	4	3	59	14.0
Blue rockfish	1	1	3	2	1	8	8.2
Bocaccio	8	2	0	2	7	19	28.8
Brown rockfish	0	1	0	0	0	1	6.3
Copper rockfish	0	0	1	0	0	1	7.1
California scorpionfish	0	0	0	0	1	1	10.0
TOTAL	16	40	13	8	12	89	

TABLE 4. Fishes Which Moved Distances Greater Than 10 Km.

Species	*Tagging location*	*Tagging date*	*Recapture location*	*Recapture date*	*Days at liberty*	*Distance moved (Km)*
Olive rockfish	Los Angeles Breakwater	11-21-77	Huntington Beach	10-28-78	342	18
Bocaccio	Oil Platform A	8-9-78	Point Arguello	8-23-80	745	111
Olive rockfish	Palawan Liberty ship	11-27-79	Los Angeles Breakwater	9-11-80	289	33
Olive rockfish	Palawan Liberty ship	8-14-80	Palos Verdes Peninsula	9-14-80	32	12
Bocaccio	Oil Platform A	8-9-78	Santa Maria River Mouth	11-8-80	822	148
Bocaccio	Palawan Liberty ship	8-14-80	Palos Verdes Peninsula	11-23-80	102	13
Bocaccio	Oil Platform A	8-9-78	Santa Monica Bay	2-15-81	921	111
Bocaccio	Oil Platform A	8-9-78	Santa Cruz Island	3-16-81	950	20
Blue rockfish	Santa Rosa	5-23-79	San Miguel Island	6-28-81	767	43
California scorpionfish	Santa Barbara	5-14-80	Point Mugu	10-5-81	510	56
Bocaccio	Oil Platform B	8-13-78	Gaviota	6-23-83	1,775	56
Bocaccio	Oil Platform B	12-2-79	Santa Monica Bay	6-29-83	1,305	111

TABLE 5. Maximum Number of Days at Liberty for Fishes Recaptured at Tagging Sites.

Species	*Days at Liberty*
Black-and-yellow rockfish	58
Blue rockfish	526
Bocaccio	827
Brown rockfish	108
Copper rockfish	1,317
Gopher rockfish	754
Grass rockfish	409
Kelp rockfish	1,109
Olive rockfish	540
Starry rockfish	111
Treefish	1,109
Vermilion rockfish	404
Widow rockfish	840
Yellowtail rockfish	876
Lingcod	285
California scorpionfish	670

Bocaccio

Juvenile bocaccio are known to inhabit waters shallower than 20 m during their first year of life (Moser 1967), and to seek deeper water with age (Feder et al. 1974). Because most adult fish occur at depths too great to permit tagging, no tagging studies have been conducted on this species. Love (1981) provided only indirect evidence of bocaccio movement.

During this study, we were fortunate to locate large aggregations of juvenile bocaccio, as well as some adults, in water shallow enough to permit tagging. Of 66 recaptured bocaccio, 19 traversed distances of 0.9 to 148 km. All were tagged as juveniles (217–235 mm TL) in water shallower than 55 m. A total of seven individuals made large-scale movements (Table 4). Nearly all had moved to depths of 135 to 230 m. Direction of movement was variable: three fish moved northward along the coast, 3 moved southward, and one moved across the Santa Barbara Channel to Santa Cruz Island (Table 4). No movement of adult bocaccio was documented. All adult fish (472–655 mm TL) were recaptured at their sites of tagging after periods of up to 827 days (Table 5).

These data support studies which suggest that juvenile bocaccio inhabit shallow water during their first few years and move into deeper water as they age. Movement seems to diminish before the fish reach a length of approximately 470 mm.

According to Phillips (1964), 50% of bocaccio mature at a length of 16.5 in (420 mm) at 4 years of age. This suggests that prereproductive bocaccio are relatively mobile but eventually become sedentary after maturing and moving to deeper water habitat.

Brown rockfish

Data collected by Lenarz (Pers. commun.) indicate that juvenile brown rockfish inhabit shallow waters within San Francisco Bay. At approximately 3 years of age, they leave the bay and enter the open ocean. The longest movement noted by Lenarz was over 50 km. Of 16 brown rockfish tagged during this study, a single individual moved 2.4 km along the L.A. Breakwater during 77 days at liberty.

Copper rockfish

In Central California, Miller and Geibel (1973) found that copper rockfish wandered extensively over short distances. The longest movement recorded in their study was 1.5 miles (2.4 km). Of 15 copper rockfish recaptured during this study, 14 were recaptured at the tagging site. One made a small-scale movement of 2.6 km between nonadjacent oil platforms during 136 days at liberty.

California scorpionfish

Movements of 6 miles were documented for California scorpionfish by Turner et al. (1969). During the present study, one scorpionfish moved more than 50 km (Table 4). Additional data from an earlier tagging study conducted by the California Department of Fish and Game indicate that this species is highly mobile, capable of traveling over 200 km (Table 6). Of 302 California scorpionfish tagged from 1972–1975 by Department divers, 42 were recovered after 11 to 1,981 days at liberty.

Movement was shown by 16 (38%) of the recovered individuals; eight of these made small-scale movements. Large-scale movements were made by the other eight, including four fish which moved from Santa Monica Bay (Redondo Canyon Artificial Reef) to the vicinity of the Coronado Islands, a journey of 218 km (Table 6). One individual covered this distance within 112 days.

The Coronado Islands were the site of some of the largest aggregations of California scorpionfish reported by Taylor (1963). One such aggregation was found to consist almost entirely of gravid females. California Department of Fish and Game landing records from 1970–1977 show a marked increase in the summer California scorpionfish catch in Fish and Game Block 916, an area of the ocean, 10 nautical mi × 10 nautical mi, which includes the Coronado Islands. The catch from this block, generally a few hundred pounds per month for the period January to April, peaks at 20,000–60,000 lb per month during June, July, or August and then tapers off to a few hundred pounds again by year's end. In other areas, there is a summer increase in landings which may be related to small-scale, localized migrations such as those described by Turner et al. (1969). Nowhere, however, does the magnitude of the increase approach that found in Block 916.

Catch data from the California Department of Fish and Game's Sea Survey program indicate that California scorpionfish have been taken on occasion by trawl, fished from the surface to 10 fathoms in water up to 200 fathoms in depth. California Department of Fish and Game gill net logs indicate that California scorpionfish are often taken in barracuda drift gill nets fished 2–8 fathoms beneath the surface over bottom depths up to 100 fathoms.

DISCUSSION

Results of this study are in agreement with other rockfish tagging studies, and provide additional evidence that most rockfishes are sedentary or move only limited distances. Although movement was documented for only five species of rockfishes, limited movement by other species may have occurred. The small-scale movements noted during this study were mainly between adjacent oil platforms, closely situated artificial reefs, or points along the L.A. Breakwater.

TABLE 6. Summary of California Scorpionfish Tag Returns Indicating Movement.

Tagging date	*Tagging location*	*Recapture date*	*Recapture location*	*Number of days at liberty*	*Distance moved (Km)*
8-7-72	Hermosa Artificial Reef	8-17-72	King Harbor	11	1.6
12-27-74	Redondo Canyon Artificial Reef	5-11-76	Palos Verdes Peninsula	501	5.8
1-2-75	Redondo Canyon Artificial Reef	2-20-77	Palos Verdes Peninsula	780	6.3
1-3-75	Redondo Canyon Artificial Reef	4-30-78	Los Angeles Breakwater	1,184	20.9
1-3-75	Redondo Canyon Artificial Reef	7-23-77	Seal Beach	932	40.2
1-10-75	Redondo Canyon Artificial Reef	6-14-80	King Harbor	1,981	1.1
1-14-75	Redondo Canyon Artificial Reef	8-4-76	Coronado Islands	568	218.0
1-14-75	Redondo Canyon Artificial Reef	11-1-75	Los Angeles Breakwater	292	24.1
1-14-75	Redondo Canyon Artificial Reef	6-12-75	Palos Verdes Peninsula	150	6.3
1-17-75	Redondo Canyon Artificial Reef	6-1-75	King Harbor	136	1.1
1-20-75	Malibu Artificial Reef	10-31-75	Paradise Cove	285	8.9
1-23-75	Redondo Canyon Artificial Reef	5-26-76	Horseshoe Kelp	489	29.0
1-23-75	Redondo Canyon Artificial Reef	8-31-77	Coronado Islands	961	218.0
1-31-75	Redondo Canyon Artificial Reef	7-15-77	Coronado Islands	896	218.0
3-19-75	Redondo Canyon Artificial Reef	7-8-75	Coronado Islands	112	218.0
5-6-75	Hermosa Artificial Reef	8-18-77	Palos Verdes Peninsula	933	8.0

Limited movements were readily documented for species tagged in these areas because of the presence of well defined, isolated structures which enabled anglers to accurately pinpoint recapture locations. Movements of a similar magnitude within a larger reef system, e.g. Cortes Bank, would be difficult to document.

Movement by three midwater species; olive rockfish, blue rockfish and bocaccio, was documented for numerous individuals. Movements by olive and blue rockfishes were characteristically limited, with occasional fish making large-scale movements. A relatively high percentage of bocaccio, however, moved distances greater than 10 km (Table 4). Movement by two benthic species; brown rockfish and copper rockfish, was observed for only one individual of each species. In both instances, movement was small-scale. One California scorpionfish, considered a sedentary species, moved more than 50 km during this study. Unpublished data from an earlier tagging study indicate that the California scorpionfish is a highly mobile species, capable of traveling over 200 km. The large-scale movement of four California scorpionfish from Santa Monica Bay to the Coronado Islands, catches of this species in midwater trawls and drift gillnets in depths up to 10 fathoms, and the tremendous increase in number near the Coronado Islands during their spawning period, suggest that California scorpionfish may take part in an annual migration to the vicinity of the Coronado Islands during the summer.

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HABITAT AND PRODUCTIVITY OF COOPER'S HAWKS NESTING IN CALIFORNIA [1]

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I studied 52 nesting areas of Cooper's Hawks, *Accipiter cooperii.* Of 77 nests, 75 were in live oak trees, *Quercus aqrifolia* and *Q. wislizenii.* Distances between adjacent active nests averaged 1.6 km in the Sacramento Study Area and 2.1 km in the Southern California Study Area. Nesting area re-occupancy was 80%, and 50% of the nesting attempts were in rebuilt nests. Incubation period was estimated at 34–37 days. Of 55 nesting attempts, mean number of eggs laid was 4.0, mean number hatched was 3.1, and mean number of young fledged was 2.3. I found live oaks to be the primary nesting habitat of Cooper's Hawks in California. Low productivity during the first two years of study was largely due to two years of drought.

INTRODUCTION

Of the *Accipiter* hawks occurring in North America, Cooper's Hawks have the widest nesting distribution south of Canada (AOU 1957). Schriver (1969), Hackman and Henny (1971), and Henny and Wight (1972) documented population declines of Cooper's Hawks in the eastern U.S. Henny and Wight (1972) compared data for pre- and post-pesticide populations and found a 24% decline in nesting productivity. In the western U.S., Snyder et al. (1973) correlated eggshell thinning with DDE content in Cooper's Hawk eggs collected in 1969–71 in Arizona-New Mexico. Productivity studies such as those made by Reynolds and Wight (1978) of accipiters in Oregon, and by Walton (unpublished) of Cooper's Hawks in the Coast Ranges of California are needed to determine the status of Cooper's Hawk populations in the western United States.

Some investigators (Thelander 1973, Olendorff and Kochert 1977) felt that a major cause of population declines in some species of raptors is habitat encroachment by man. Many California Cooper's Hawks nest in oak-wooded hills, and these hills are subject to increasing suburban development. Determination of habitat requirements of Cooper's Hawks becomes increasingly important as this trend continues.

The purpose of this study was to record fledging rate and other aspects of reproductive biology, and habitat characteristics of Cooper's Hawks in interior and southern California.

METHODS

This study was conducted in three areas of California: the Sacramento Study Area in the foothills east of Sacramento (Sacramento, Placer and El Dorado counties; 30–200 m elevation); the Stockton Study Area in the foothills east of Stockton (Calaveras county; 120–420 m elevation); and the Southern California Study Area in the hills north and east of San Diego (Riverside and San Diego counties; 105–1095 m elevation). No absolute boundaries were set, and all territories in each study area were not located. Of 52 nesting areas studied, 27

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were in the Sacramento Study Area, seven in the Stockton Study Area, and 18 in the Southern California Study Area. All cooperators who showed me nesting areas were falconers.

A nesting area was characterized by the presence of one or more nests in a single stand of trees. A nesting area was considered occupied if Cooper's Hawks were sighted in the area or if evidence—such as molted feathers, vocalizations, a newly-built nest, or eggs—was found. Newly-built or rebuilt nests were identified by the presence of freshly broken sticks, a well-formed nest bowl, bark lining the nest, eggs, or an incubating female. Nesting areas in which eggs were found were considered active (Postupalski 1974). Occupied nesting areas were the basis for calculating rates of reoccupancy, while only active nesting areas were used for productivity calculations.

I recorded nesting productivity, biology, and habitat characteristics in the Sacramento Study Area during the springs of 1977 and 1978, and collected additional productivity data in 1979 and 1980. Productivity and habitat data were collected in the Southern California Study Area in 1978, and habitat data only were collected in the Stockton Study Area in 1978.

In 1977 each active nesting area in the Sacramento Study Area was visited an average of five times, in 1978 seven times, and in 1979 and 1980 three times. The mean for the Southern California Study Area was four visits per nest. As a precaution against egg-eating mammals that may have followed the scent trail of the investigator to the nest, napthaline crystals were liberally applied around the trunk of all nest trees visited (Fyfe and Olendorff 1976).

Incubation time and dates of laying, onset of incubation, and hatching were estimated from data collected during each visit. Number of eggs, whether eggs were warm or cold, and age of young were noted. Some nests were visited at both the time of egg-laying and at the time of egg pipping or hatching, allowing me to estimate the incubation period.

To measure overall productivity I attempted to visit the nest (i) sometime before the eggs hatched to count the number laid, (ii) shortly after the eggs had hatched to determine the number hatched, and (iii) when the young were about three weeks of age to count the young that survived to fledging stage. Due to the danger of causing premature fledging while climbing nest trees and the difficulty in locating nestlings in tree foliage, nestlings were counted as fledged at the time that most are just able to walk out of the nest and onto nearby branches, i.e., three weeks old. A nest was considered successful if at least one nestling survived to fledging (Postupalski 1974).

Historical data, dating from 1974, on 15 nesting areas in the Sacramento Study Areas, four in the Stockton Study Area, and three in the Southern California Study Area were gathered from cooperators for the purpose of calculating reoccupancy rates.

Occupied nests were examined to determine if they had been rebuilt or were new nests. The height of the nest from the ground was measured to the nearest 0.1 m using a weighted, marked line lowered from the top edge of the nest to the ground. Elevation of nesting areas was estimated to the nearest 5 m using U.S. Geological Survey topographical maps. These maps were also used to estimate distances between active nests. The areas immediately around nests and the general surroundings were examined for the tree species present, other vegetation, vegetation structure, terrain, and proximity to water. I made no attempt to quantify vegetation structure.

RESULTS

Nesting Environment

Nest Tree Species

Vegetation in the study area was typical oak woodland (Barbour and Major 1977). The following trees predominated in the Sacramento and Stockton Study Areas: digger pine, *Pinus sabiniana,* Fremont cottonwood, *Populus fremontii,* California valley oak, *Quercus lobata,* blue oak, *Q. duglasii,* and interior live oak, *Q. wislizenii.* Predominant in the Southern California Study Area were: California coast live oak, *Q. agrifolia,* and California sycamore, *Platanus racemosa.*

Of the 77 nests studied, all but two were found in live oak trees. The species of live oak utilized depended upon which was present in that area. The other two nests were found in a blue oak and a California sycamore. Both of these trees were growing in stands of live oak.

Nest Grove

Most nests were in stands of six or more trees; however, two were in lone oak trees 30–40 m from the nearest other tree. The structure of these stands was characterized by one or more trees growing close enough so that their crowns joined to form a single continuous canopy. The understory was composed of vertical tree trunks and large branches with few small branches or leaves. Ground cover was absent or consisted of short grass and/or poison oak (*Rhus diversiloba*), with few other shrubs.

Most nest trees (79%) were in flat areas, usually bottom lands between hills. These areas appeared to be the most favorable for growth of groups of tall live oak. Some nest trees (21%), however, were found on steep hillsides.

Nests were generally in one of the most mature trees of the stand, where the canopy was highest and the ground cover most sparse. Nests were built in, or just below the canopy, ¾ to ⅘ of the height of the tree. Forty-eight nests averaged 10.1 meters above ground (SD=2.0, range: 5.7–14.0 m). Nests in interior live oak were always in a fork of the main trunk, while 44% of the nests in California coast live oak were out on a branch, away from the trunk. These differences in nest placement were apparently due to differences in growth patterns of the two oak species.

Surrounding Area

While stands of trees containing nests were usually similar in structure, this was not the case for the surrounding area. In the northern part of the Sacramento Study Area, nests were in one large, semi-continuous stand of interior live oak, digger pine, and shrubs, all of which formed a thick, jungle-like cover over the hills around Folsom Lake. A few miles to the south, nests were in small groups of interior live oak, mixed with some blue oak, valley oak, and digger pine, all in gently rolling grasslands. At somewhat higher elevations (Stockton Study Area) nest stands were in flat areas between steep, rocky hillsides dotted with oak and digger pine. Hollows between the chaparral covered hills of the Southern California Study Area contain large California coast live oak that are used by Cooper's Hawks as nest trees.

Water

Nests were located as much as 2.0 km, from the nearest water. These large distances occurred late in the nesting cycle, when many of the small streams were dry.

Two consecutive years of drastically reduced rainfall preceded the nesting attempts of 1977 (Figure 1). Rainfall nearly quadrupled in the winter preceding the 1978 nesting season, and remained high for the following two years.

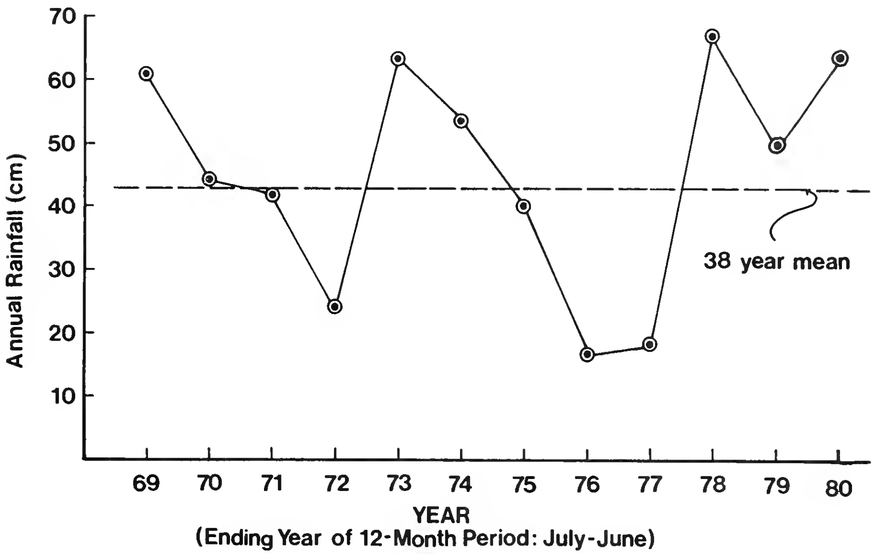

FIGURE 1. Twelve years of annual rainfall recorded for Sacramento, California. Source: U.S. Weather Bureau.

Spacing of Territories

Densities of nesting Cooper's Hawks were not calculated. When adjacent nesting areas were discovered, the distances between active nests were measured. Distances between active nests of adjacent nesting areas in the Sacramento Study Area averaged 1.6 km (SD=0.6, range: 0.7–2.5 km, n=13). In the Southern California Study Area distances averaged 2.1 km (SD=0.5, range: 1.0–2.6 km, n=8).

Nesting Biology

Unless specifically noted, the data presented in this section were collected in the Sacramento Study Area.

Nesting Area Reoccupancy

The rate of nesting area reoccupancy was 80% (33 nesting areas reoccupied of 41 rechecked). Seven nesting areas were active in every year of this four-year study. (One of three nesting areas checked for seven consecutive years was active in all seven years.) The previous year's nest was reused in 32% of the nesting areas occupied in consecutive years. This occurred in 11 of 34 reoccupations. Half of all nesting attempts were in rebuilt nests.

In one nesting area in the Southern California Study Area which was monitored for 5 consecutive years, the same nest site was used each year. During the winter prior to the fifth (1978) nesting, the old nest was blown down and a new nest was built in the same fork of the tree.

Age of Breeding Birds

Five (8%) of 61 nesting females observed were in immature plumage; all 29 males observed were in adult plumage.

Egg Laying and Incubation

Egg laying ranged from 6 April to 10 May. Data from two nests indicate that eggs were laid on alternate days. The mean estimated date of onset of incubation was 28 April (SD=5.4, N=12). This date is based on the assumption that incubation begins with the laying of the third egg (Meng 1951). However, incubation may be initiated some time later. Two nests were found containing three cold (unincubated eggs). This was the complete clutch of eggs for one of the nests, and all three eggs eventually hatched. Two more eggs were laid in the other nest and all of the eggs hatched.

The incubation period was estimated to be 34–37 days, and appeared to be variable. Thirty-five days after a nest was discovered with two eggs, it was found containing three newly-hatched chicks and one pipping egg. In another nest, four of a five egg clutch were pipping 37 days after the nest had contained three cold eggs, and 42 days after the nest had contained only one egg.

Hatching

The mean date of hatching in the Sacramento Study Area for 1977–1980 was 1 June (N=41, SD=9.9 days). Mean hatch date in the Southern California Study Area for 1978 was 28 May (N=16, SD=11.7 days), 9 days earlier than that in the Sacramento Study Area for that year ($\overline{X}$=6 June, N=12, SD=6.2 days).

Nesting Productivity

Mean number of eggs laid per nest was 4.0, mean number hatched was 3.1, and mean number of young fledged was 2.3 (Table 1). The overall hatchability was 77% (Table 2). Eggs did not hatch for several reasons: 10% disappeared before hatching (or just after hatching and before the nest was checked by investigators); 7% remained unhatched; and 5% were eaten, abandoned, cracked, or broken. Some eggs may have hatched and the young disappeared before the nest was checked so the hatchability reported is probably conservative. Seventy-five percent of the young that hatched survived to three weeks of age (Table 2). Six percent disappeared (cause not determined). Eighteen percent were lost to causes including death shortly after hatching, presumed starvation of a "runt," predation or man. At least 7% of the young were removed from nests by humans. This percentage is probably abnormally high; biased by my use of nesting areas frequented by falconers. Eighty-five percent of the nesting attempts were successful (Table 2). Since I did not include attempts that failed before eggs were laid, this figure is high.

TABLE 1. Productivity of Nesting *Accipiter cooperii* in Sacramento and Southern California Study Areas.

		Mean No. Per Nest						
Year	*Study Area*	*Eggs*		*Hatch*		*Fledge*		*No. Nests*
1977	Sacramento	4.0	(0.58)*	2.4	(1.44)	1.4	(1.04)	12
1978	Sacramento	3.8	(0.72)	3.0	(1.13)	2.5	(1.08)	11
1978	Southern Calif.	3.7	(0.45)	3.0	(1.20)	2.1	(1.51)	18
1979	Sacramento	4.3	(0.45)	3.9	(0.63)	3.6	(0.74)	7
1980	Sacramento	4.9	(0.64)	4.0	(1.07)	3.3	(0.88)	7
	Overall	4.0	(0.67)	3.1	(1.29)	2.3	(1.38)	55

* Standard deviation

TABLE 2. Hatching Success, Fledging Success and Nesting Success of *Accipiter cooperii* in Sacramento and Southern California Study Areas.

		Eggs	*Hatch*		*Fledge*		*Nests*	*Successful*	
Year	*Study Area*	*No.*	*No.*	*%*	*No.*	*%*	*No.*	*No.*	*%*
1977	Sacramento	48	29	60	17	59	12	9	75
1978	Sacramento	42	33	79	27	82	11	11	100
1978	Southern Calif.	67	54	81	37	69	18	13	72
1979	Sacramento	30	27	90	25	93	7	7	100
1980	Sacramento	34	28	82	23	82	7	7	100
	Overall	221	171	77	129	75	55	47	85

DISCUSSION

Reynolds and Wight (1978) reported mean distances between Cooper's Hawk nests of 5.0 km and 5.5 km in western Oregon, and 3.5 km in eastern Oregon. Meng (1951) stated that the two closest nests he studied in New York were 2.4 km apart. Brandt (1951) gave 1.6 km as the approximate distance between nests in Arizona. Fitch, Glading and House (1946) reported two nests in California to be 1.6 km apart. My averages of 1.6 km (Sacramento Study Area) and 2.1 km (Southern California Study Area) between active nests suggest densities in California's oak woodlands as high as any yet recorded for Cooper's Hawks.

Cooper's Hawks nest in many tree species throughout North America (see Asay 1980). Grinnell and Miller (1944) stated for Cooper's Hawks in California: "Nesting sites are predominantly in riparian growths of deciduous trees, as in canyon bottoms and on river flood-plains, although live oaks are often used." It is not clear why the emphasis was placed on riparian-deciduous trees. In their list of references to nest trees, only 4 of 11 were riparian-deciduous trees; four others were oaks, and the remaining three were conifers. Perhaps Grinnell and Miller (1944) were influenced by Bent (1937) who reported: "In Arizona we found several nests of Cooper's Hawks generally high up in the tops of the giant cottonwoods or sycamore in the mountain canyons. . . . In Texas these hawks nest in the lofty tops of the heavily timbered deciduous forests in the river bottoms."

Nearly all references to trees used by nesting Cooper's Hawks in California that appeared after Grinnell and Miller (1944) report the use of live oaks (Fitch, et al. 1946, Wiley 1975, Kline 1975, Walton unpublished). In addition, Gaines' (1974) found no Cooper's Hawks nesting in riparian habitats in the Sacramento Valley. While it is apparent that Cooper's Hawks may nest in many different tree species and in different habitats, the primary nesting habitat for Cooper's Hawks in California is live oak woodlands.

Reynolds and Wight (1978) reported, for Cooper's Hawks in Oregon, a nesting area reoccupancy rate of 21%, and found three years to be the maximum that a nesting area was occupied. They did not observe reuse of an old nest. The much higher rate of nesting area reoccupancy in the present study, 80%, together with frequent reuse of old nests, might be a result of California populations being resident while those in Oregon are migratory.

Incubation time calculated in this study, 34–37 days, supports the 36 day incubation time given by Meng (1951), but is longer than the 30–32 days reported by Reynolds and Wight (1978), and the 24 days given by Bent (1937) and repeated by Mallette and Gould (undated). Bent (1937) was not reporting from direct observation, but stated, "Incubation . . . is said to last for 24 days." Reynolds and Wight did not detail their methods for determining incubation period. Meng (1951), on the other hand, made daily observations of many nests and corroborated his observations by timing eggs kept in an incubator. Curiously, Meng (1951) made no mention of variability in incubation period. My data, although much less complete than Meng's (1951), indicate that variability does occur.

Reynolds and Wight (1978) recorded greater losses during the nestling period than during incubation. In this study, however, hatching and fledging success were generally equivalent, and both values were greater than or equal to those of Reynolds and Wight (1978).

Productivity and nesting success appears to be greatly affected by drought. In 1977, following 2 years of low rainfall, hatching and fledging rates in the Sacramento Study Area were low (Tables 1 and 2). When rainfall increased prior to the 1978 breeding season, nesting success and mean fledging number increased markedly and remained high in succeeding years. In just three years this population had experienced productivity changes from very low to very high levels.

My mean fledging rate (2.3) is considerably lower than that recorded by Walton (unpublished; $\overline{X}=3.4$, $n=86$) in the California Coast Range, yet is not significantly different than those recorded by Craighead and Craighead (1956; $\overline{X}=2.8$, $n=13$) in Michigan and Reynolds and Wight (1978; $\overline{X}=2.1$, $n=24$) in Oregon. (Reynolds and Wight [1978], however, probably overestimated fledging rate because they included in their sample nests discovered after the eggs had hatched.) Standard deviation given by Reynolds and Wight (1978; SD=1.56) was as large as that recorded in this study (1.38), indicating a great degree of variability in nesting success of Cooper's Hawks.

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POPULATION STUDIES OF ROCK CRAB, *CANCER ANTENNARIUS,* YELLOW CRAB, *C. ANTHONYI,* AND KELLET'S WHELK, *KELLETIA KELLETII,* IN THE VICINITY OF LITTLE COJO BAY, SANTA BARBARA COUNTY, CALIFORNIA

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Populations of the rock crab, *Cancer antennarius,* yellow crab, *C. anthonyi,* and Kellet's whelk, *Kelletia kelletii,* were studied in Little Cojo Bay, near Pt. Conception, California, from October 1980 to June 1981, using commercial crab traps to obtain samples. Effort consisted of 1,104 traps soaked for a total of 26,256 hr and total catch was 4,124 rock crabs, 656 yellow crabs, and 23,577 whelks.

There were significant differences in relative abundance of all species among the six stations and four quarters. Rock crabs were most abundant in the fall quarter and were caught more frequently at stations with a higher proportion of sand substrate. Yellow crabs were most abundant in the summer and also were caught more frequently in sandy habitat. Rock crabs decreased in relative abundance with increasing depth. The opposite was true for yellow crabs, indicating competition may be a factor in their distribution. Recruitment of small rock crabs (less than 82 mm carapace width) was important in contributing to the high mean catch per trap hour in the fall, while the apparent movement of large male and female yellow crabs into the study area was responsible for the high relative abundance in the summer. This movement of yellow crabs corresponded with a decrease in percentage of ovigerous females in adjacent deeper areas.

Kellet's whelks were ubiquitous and abundant and occurred most frequently at the station consisting of flat bedrock with a high percentage cover of giant kelp, *Macrocystis pyrifera,* and the brown alga, *Pterygophora californica.* Whelks were least abundant at stations consisting mostly of sand or medium relief bedrock and reef. Stable populations of whelks were observed at two of the deep stations. A decline in relative abundance occurred at shallow stations when bottom temperatures reached their annual minimum in the spring. This was the only quarter in which temperatures at shallow stations were lower than those at deep stations.

INTRODUCTION

Little Cojo Bay, near Pt. Conception, California (Figure 1) was the site of a proposed liquified natural gas (LNG) terminal and marine facilities. Western LNG Terminal Associates was granted California Public Utilities Commission and National Pollution Discharge Elimination System permits for construction and operation of the LNG facility. Subsequently, Western LNG developed a marine environmental study plan to obtain quantitative baseline data for algal, fish, and invertebrate populations in the vicinity of the LNG terminal site. This report describes the results of a 1-yr preconstruction study, conducted by the California Department of Fish and Game, on two commercially important crustaceans, the rock crab, *Cancer antennarius,* and yellow crab, *C. anthonyi,* and a gastropod of potential commercial importance, the Kellet's whelk, *Kelletia kelletii.* Rock and yellow crabs are the objects of an expanding commercial fishery, particular-

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ly in the Santa Barbara and Channel Islands areas (Best and Oliphant 1965, Frey 1971, John Sunada, Calif. Dept. Fish and Game, pers. commun.). At the time of writing, small quantities of Kellet's whelks were being sold locally in the Santa Barbara area.

STUDY AREA

The study area consisted of six stations, three at a depth of 25 to 40 ft below MLLW (stations T30, CE30, CW30), and three at a depth of 45 to 60 ft below MLLW (stations T60, CE60, CW60) (Figure 1). The English system of depth was used to delineate stations in order to correspond with available nautical charts and the depth sounder of the research vessel. Stations T30 and T60 contain the site of the proposed trestle for receiving LNG tankers and the proposed seawater intake and discharge systems for the terminal. The CE and CW stations were controls located approximately 1 nautical mile east and west of the terminal site. The sea floor is characterized by low to medium relief (less than 1.5 m) shale bedrock intermixed with areas of cobble, boulder, and sand. This, along with numerous large holdfasts of the giant kelp, *Macrocystis pyrifera,* provides suitable habitat for crabs and whelks.

METHODS AND MATERIALS

The study occurred during four quarters defined as follows: fall, September–November 1980; winter, December 1980–February 1981; spring, March–May 1981; and summer, June–August 1981. Quarterly at each station on 2 consecutive days, 18 to 26 commercial crab traps were baited with fish and set in lines approximately parallel to shore. Traps were set at least 60 m apart along depth contours at 5-ft intervals (25, 30, . . . 60 ft below MLLW). Traps were soaked overnight from 17 to 29 hr (mean = 23.3 hr), with the exception of 20 traps set at CW60 during the winter quarter which, due to poor weather, were not retrieved until they had soaked 49 hr. Bait was replaced in each trap prior to each set. Each crab trap fished within a station was considered a replicate for analysis of data. Number of replicates completed at each station by quarter was as follows; fall, 36 to 50; winter, 38 to 40; spring, 50; summer, 50 (Figure 2).

Rock and yellow crabs and Kellet's whelks were removed from traps and counted. Carapace width (CW) for crabs was measured to the nearest 1.0 mm in a straight line distance across the back between the notch formed on each side by the two anterolateral teeth at the widest part of the carapace. Carapace widths were used as an indicator of recruitment of young crabs to the traps in the study area. Additional information recorded for each crab included sex, and for females reproductive condition (presence and stage of development of egg sponge).

Temperature profiles at 2-m intervals between the surface and bottom were obtained at each station during each quarter, but not necessarily on crab trapping days. A Martek Mark VI Water Quality Analyzer was used exclusively.

Number of crabs and whelks caught per trap and per trap-hour are estimates of relative abundance. Data on the distribution of catch-per-trap, at each station for each quarter, were tested for normality using the Komogorov-Smirnov goodness of fit test (Smirnov 1939). In the majority of cases, distributions were significantly different from normal ($P \leq 0.05$). Bartlett's test for homogeneity of variances (Sokal and Rohlf 1969) indicated heteroscedasticity (inequality of

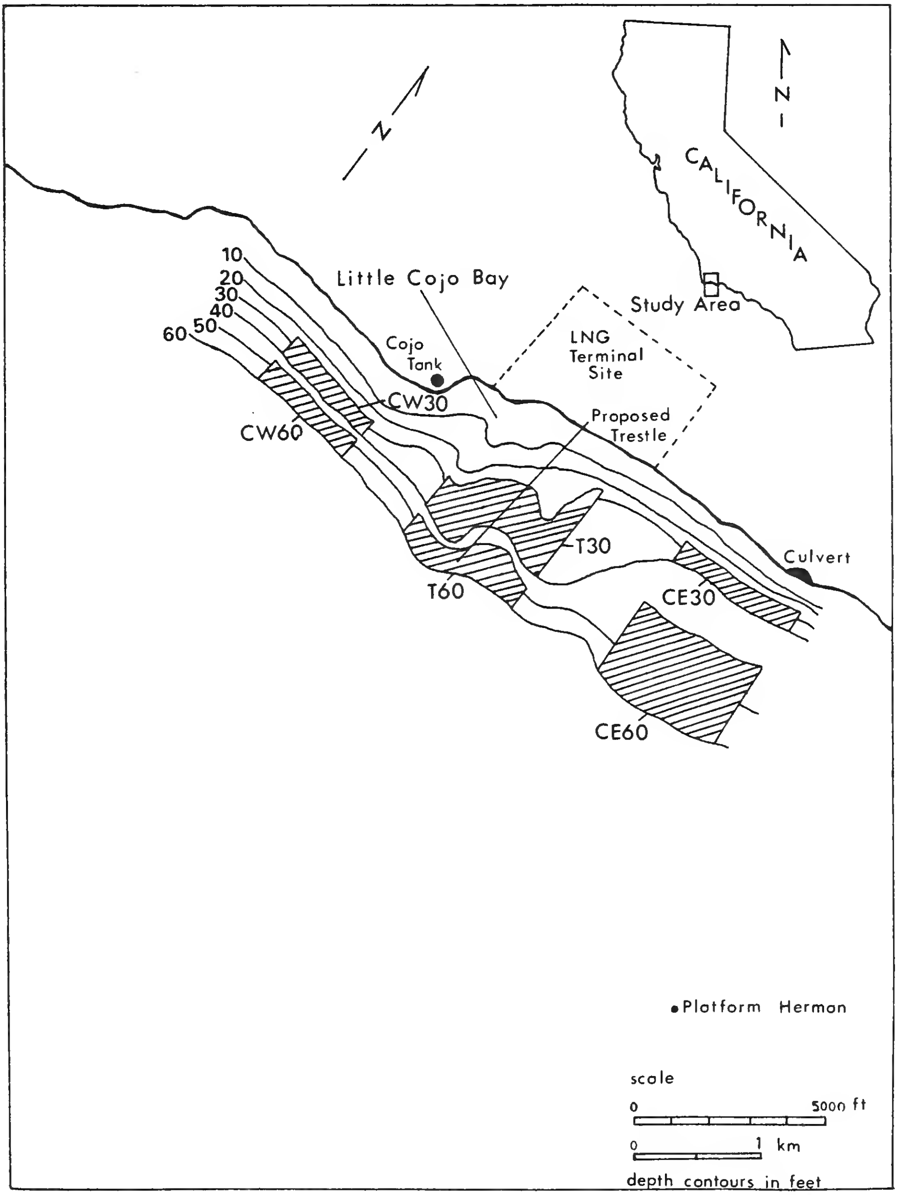

FIGURE 1. Location of stations for crab and whelk trapping study.

variances among samples) for the six stations and four quarters (this test is more discriminating than tests for normality).

The Mann-Whitney U test (Mann and Whitney 1947) and Kruskal-Wallis test (Kruskal and Wallis 1952) were then used to compare relative abundance of rock crabs, yellow crabs, and Kellet's whelks among the six stations, groups of stations, and four quarters. Catch-per-trap (CPT) and catch-per-trap-hour (CPTH) were tested for significant differences ($P = 0.05$). All results will be discussed but those reported here will be for CPTH only. Dunn's Multiple Comparisons (Dunn 1964) were used to specify stations(s) or quarter(s) responsible for significant differences in average CPTH.

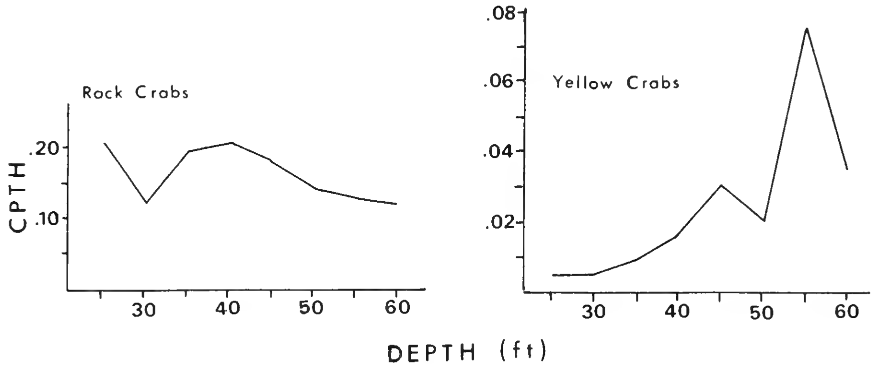

FIGURE 2. Mean CPTH for rock crabs and yellow crabs by 5-ft depth contour intervals, stations and quarters combined.

RESULTS

Total Effort and Catch

A total of 1,104 traps was soaked for 26,256 hr. Sampling occurred in October and December 1980 and March, April, and June 1981. Kellet's whelks were by far the most abundant of the 25 species of invertebrates occurring in the traps, followed by rock crabs (Table 1).

TABLE 1. Total Catch of Rock Crabs, Yellow Crabs, and Kellet's Whelks, and Total Trap Effort by Quarter and Station.

	Quarter				
Species	*Fall*	*Winter*	*Spring*	*Summer*	*Total*
Rock crab	1,454	726	1,110	834	4,124
Yellow crab	107	73	125	351	656
Kellet's whelk	6,018	5,872	4,784	6,903	23,577
Traps pulled	257	237	300	300	1,104
Trap hours	6,532	5,965	6,730	7,029	26,256

	Station						
Species	*T30*	*T60*	*CW30*	*CW60*	*CE30*	*CE60*	*Total*
Rock crab	298	383	1,239	859	796	549	4,124
Yellow crab	13	64	48	416	51	64	656
Kellet's whelk	2,512	3,863	2,361	2,899	3,358	8,584	23,577
Traps pulled	178	176	190	190	183	187	1,104
Trap hours	4,233	4,091	4,427	4,978	4,169	4,358	26,256

Rock Crab Abundance and Distribution

There were significant differences in average CPTH for rock crabs among stations for each quarter (Table 2), primarily due to relatively low abundance at the trestle stations and relatively high abundance at the shallow west control station. Highest quarterly average CPTH, 0.37, and single highest CPT, 28, occurred at the latter station. The deep trestle station had the lowest quarterly average CPTH, 0.02.

TABLE 2. Significance Levels of Kruskal-Wallis and Mann-Whitney Tests of Mean Catch per Trap Hour for the Rock Crab, Yellow Crab, and Kellet's Whelk.

Part 1. By quarter among six stations

Species	*Fall*	*Winter*	*Spring*	*Summer*
Rock crab	<0.001 *	<0.001 *	<0.001 *	<0.001 *
Yellow crab	0.007 *	0.009 *	<0.001 *	<0.001 *
Kellet's whelk	<0.001 *	<0.001 *	<0.001 *	<0.001 *

Part 2. By quarter between deep and shallow stations

Species	*Fall*	*Winter*	*Spring*	*Summer*
Rock crab	0.604	0.005 *	<0.001 *	0.056
Yellow crab	0.002 *	0.263	0.060	<0.001 *
Kellet's welk	0.007 *	0.698	<0.001 *	<0.001 *

Part 3. By station among four quarters

Species	*T30*	*T60*	*CW30*	*CW60*	*CE30*	*CE60*
Rock crab	<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *
Yellow crab	0.020 *	<0.001 *	<0.001 *	<0.001 *	0.368	0.004 *
Kellet's whelk	0.012 *	0.007 *	0.014 *	0.078	<0.001 *	0.154

* significantly different if $P \leq 0.05$

The three shallow stations combined had a significantly higher average CPTH than the three deep stations combined during the winter and spring quarters only (Table 2). When mean CPTH was partitioned by 5-ft depth intervals, a trend of decreasing relative abundance with increasing depth between 40 and 60 ft was evident (Figure 2).

There were also significant differences in CPTH for rock crabs among quarters for each station (Table 2). Highest overall mean CPTH, 0.22, occurred in fall and lowest mean CPTH, 0.12, occurred in winter and summer.

Yellow Crab Distribution and Abundance

There were significant differences in average CPTH for yellow crabs among stations for each quarter (Table 2), primarily due to the relatively high catch at station CW60. Highest quarterly average CPTH, 0.20, and single highest CPT, 23, occurred at this station. Station T30 was considerably less productive than other stations. Zero catches occurred at Station T60 in winter and at Stations T30 and CE60 in spring.

The three deeper stations combined had a significantly higher average CPTH than the three shallow stations combined during fall and summer quarters only (Table 2). When mean CPTH was partitioned by 5-ft depth intervals, a pattern was evident of increasing CPTH with increasing depth (Figure 2). Of 656 yellow crabs, 544 (82.9%) were caught in the three deep stations.

There were significant differences in CPTH for yellow crabs among quarters at all stations except the shallow east control (Table 2); at this station catches were consistently low but never zero. Highest overall mean CPTH for all stations combined, 0.05, occurred in summer, and lowest mean CPTH, 0.01, occurred in winter, although catches in fall and spring were also relatively low.

Rock Crab Recruitment

The frequency distribution of carapace widths of rock crabs caught during the fall quarter showed two modes, with a separation occurring in the 78 to 84 mm range (Figure 3). Total numbers of rock crabs less than 82 mm during the study were as follows: 63 in fall quarter; 19 in winter quarter; 8 in spring quarter; 1 in summer quarter. Mean cw among stations for fall and winter quarters was significantly less than that for spring and summer quarters. These data indicate that recruitment of smaller crabs into the study area occurred primarily in the fall quarter, but continued into the winter quarter. No crabs less than 82 mm were caught in either of the two east control stations.

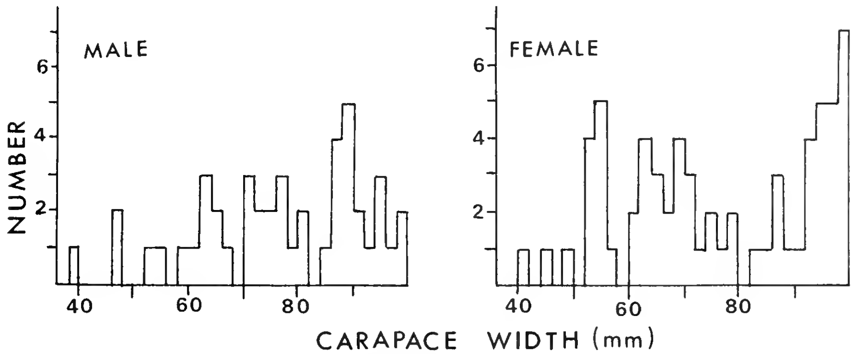

FIGURE 3. Carapace width frequency distributions (2-mm intervals) for male and female rock crabs less than 100 mm, fall quarter, stations combined.

Yellow Crab Recruitment

There was virtually no recruitment observed in the study area for small yellow crabs. Only two crabs less than 82 mm were caught; these occurred at the deep west control station.

Reproductive Condition of Female Rock and Yellow Crabs

Percentage of female crabs bearing egg sponges (i.e. ovigerous) each quarter was calculated to determine what time of year was most important for this reproductive stage (Figure 4). Although ovigerous female rock crabs were found during all quarters, percentages were higher in winter and spring. For yellow crabs, summer was peak egg-bearing season in the study area, and no ovigerous females occurred during the winter quarter.

Kellet's Whelk Abundance and Distribution

There were significant differences in average CPTH for Kellet's whelks among stations for each quarter (Table 2), primarily due to the relatively high catch at the deep east control station. Overall average CPTH at Station CE60 was 1.97, more than twice as high as the next most productive station, T60. Single highest CPT, 258, also occurred at Station CE60. Catches were relatively low at the west control stations and the shallow trestle station.

All stations except CW60 and CE60 showed significant differences in CPTH among quarters (Table 2), indicating that stable populations of whelks exist at these two stations. Overall CPTH was remarkably uniform during the fall, winter, and summer quarters (0.92, 0.98, and 0.98, respectively), and dropped to 0.71 during the spring.

Mean CPTH for the deep stations was significantly greater than that of the shallow stations in all quarters except winter (Table 2).

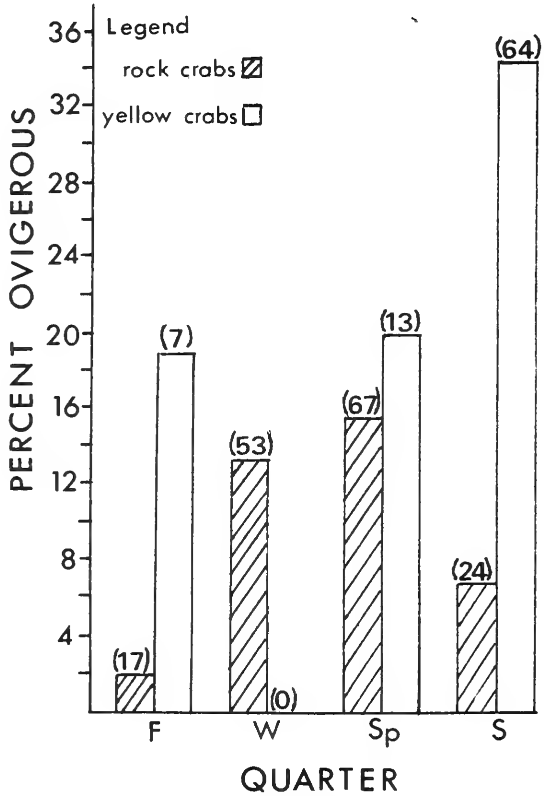

FIGURE 4. Number (N) and percentage of female rock crabs and yellow crabs bearing eggs, by quarter, stations combined.

Bottom Temperatures

Throughout the study period, recorded bottom temperatures ranged between 10 and 16 C and fell to their annual lows during upwelling season in the spring (Table 3).

TABLE 3. Bottom Temperatures at Shallow and Deep Stations, Little Cojo Bay, October 1980 to June 1981. (N) = Number of Readings.

	Temperature (C)	
Month	*Shallow (25–40 ft)*	*Deep (45–60 ft)*
October	15.5 (2)	14.8 (4)
December	15.1 (2)	14.5 (4)
March	10.4 (2)	12.1 (4)
April	12.1 (20)	11.8 (18)
June	14.9 (21)	14.4 (22)

DISCUSSION

Rock and Yellow Crab Abundance and Distribution

Significant differences among stations in CPTH for rock and yellow crabs are most likely due to substrate and bottom topography. Extensive observations were made by SCUBA divers throughout the study period. The west control stations consist primarily of sand bottom with limited areas of low relief bedrock supporting stands of kelp. The sand environment and kelp holdfasts offer maximum protection and concealment for rock and yellow crabs. These stations had the highest CPTH for both species.

The shallow east control station consisted of about half sand and half medium relief bedrock with kelp. The deep east control station contained primarily low relief bedrock and bedrock pieces with scattered medium relief rock outcrops. It had the highest percentage kelp cover among the six stations as well as a luxuriant forest of the brown alga, *Pterygophora californica*. These two stations had higher overall CPTH for rock crabs than the trestle stations and produced catches of yellow crabs about as low as the trestle stations.

The shallow trestle station had the highest percentage cover of bedrock, very little sand, and the low to medium relief rock outcrops had few crevices affording shelter for crabs. The deep trestle station consisted mostly of low relief bedrock and bedrock pieces with little kelp or brown algae. These two stations had the lowest overall CPTH for rock crabs.

Depth was an important factor in the distribution of yellow crabs during fall and summer. During winter and spring, catches were uniformly low at all stations. Opposite trends in rock and yellow crab relative abundance with increasing depth indicate that competition for space and/or food may be a factor in their distribution. Although the west control had the highest CPTH for both species, the shallow station had the highest CPTH for rock crabs and the deep station had the highest CPTH for yellow crabs.

Significant differences among quarters in CPTH for rock crabs were probably related to recruitment. Recruitment may be considered as that portion of the crab population entering the stock at a specific age or size. Reasons for recruitment, or availability of, smaller crabs to the study area include the following: i) crabs within the study area have grown to a particular minimum size and are now retained by crab traps; ii) crabs of a particular minimum size are moving into the study area. As indicators of recruitment, mean CW and numbers of small crabs were compared among stations and quarters. Results indicate that smaller rock crabs were becoming available to traps in the study area during the fall quarter; crabs less than 82 mm were important in contributing to the highest quarterly mean CPTH, which occurred in the fall.

On the other hand, significant differences among quarters in CPTH for yellow crabs were probably due to immigration/emigration of adults and changes in distribution related to the reproductive cycle. Highest quarterly mean CPTH occurred in summer, and only two crabs less than 82 mm were caught during the study. The apparent movement of larger crabs into the study area was responsible for the high mean CPTH.

Additional data from studies on the commercial fishery for yellow crabs, adjacent to the study area, showed that highest percentage of ovigerous females occurred in March during the spring quarter (Figure 5) (Reilly, unpublished data). A subsequent decline, from April to June, in the proportion of ovigerous females in commercial traps corresponded to an increase in the proportion of ovigerous females in the crab traps in this study from the spring to the summer quarter (Figure 4). This suggests that ovigerous females moved from deep water, where commercial trapping occurs, into the shallower water of the study area.

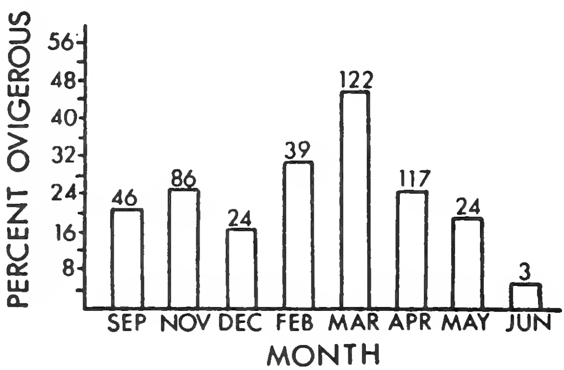

FIGURE 5. Number (N) and percentage of female yellow crabs bearing eggs by month, from commercial crab sampling.

Gear Saturation for Rock and Yellow Crabs

Beverton and Holt (1957) define gear saturation as "the tendency for the fishing power of a unit of gear to become reduced as the catch in it increases." Additional crab trapping data from this and other studies support this concept. On four occasions during periods of poor weather in the spring quarter, traps could not be retrieved until they had fished from 97 to 168 hr. These data were not used in previous analyses. A comparison was made with the four sets of CPT and CPTH data for traps fished approximately 24 hr (20.8 to 25.0 hr) at the same stations, also during the spring quarter (Table 4); CPT was fairly similar, while CPTH was always lower for the longer soak periods. This indicates that crabs inside the traps may have reached a saturation level, which may occur within 24 hr, and after that time the traps did not fish effectively. Poor weather and deterioration or dissipation of the bait may have inhibited the crabs' feeding and thus the effectiveness of the traps. On the other hand, saturation level in crab traps may be due to behavioral interaction, i.e. crabs inside the trap intimidating those outside (Miller 1978b) or other factors such as food availability or local population densities, and thus may vary within a small geographical area. For traps soaked no longer than 29 hr, highest catch of rock crabs in a single trap was 28, yet in the 97 to 168 hr soak periods, CPT was no greater than 18.

Comparison of traps soaked for 23 hr with those soaked for 49 hr at Station CW60 during the winter quarter also raises questions about effectiveness of longer soak times; CPTH was lower in the 49-hr traps for rock crabs and yellow crabs. However, in this case the data were included in the analyses because results of the Kruskal-Wallis test using CPTH were similar to those using CPT at Station CW60.

Miller (1978a, 1978b) studied differences in CPTH of *Cancer productus* between traps that were fished (crabs counted and removed) every 2 hr and traps that were not fished (crabs counted every 2 hr but not removed). He concluded that catch per unit of gear became asymptotic with soak time and that soak time for saturation was as little as 5 hr.

TABLE 4. Comparison of Catch per Trap and Catch per Trap Hour of Rock Crabs and Yellow Crabs for Different Soak Times.

Station	*Species*	*No. of traps*	*Mean soak time (hr)*	*Mean CPT*	*Mean CPTH*
T30	rock crab	25	97.0	1.3	0.014
	yellow crab	25	97.0	0.0	0.0
T60	rock crab	25	168.0	1.6	0.010
	yellow crab	25	168.0	0.2	0.001
CW30	rock crab	12	145.0	10.0	0.069
	yellow crab	12	145.0	0.2	0.001
CW60	rock crab	19	120.0	5.6	0.047
	yellow crab	19	120.0	1.4	0.012
T30	rock crab	50	25.0	1.2	0.048
	yellow crab	50	25.0	0.0	0.0
T60	rock crab	50	20.8	2.0	0.096
	yellow crab	50	20.8	0.2	0.008
CW30	rock crab	50	21.5	6.4	0.299
	yellow crab	50	21.5	0.2	0.007
CW60	rock crab	50	22.8	4.4	0.192
	yellow crab	50	22.8	2.0	0.088

Bottom Temperature and Crab Relative Abundance

Bottom temperatures were fairly uniform throughout the study period except for the spring quarter. No trend in crab abundance was apparent between quarters that was similar for all stations. However, overall catch increased from winter to spring quarter as temperatures dropped to their annual lows.

Kellet's Whelk Abundance and Distribution

Kellet's whelks occurred most frequently at Station CE60. This station consists of a low percentage of sand substrate, a relatively flat bedrock bottom, and the highest percentage kelp cover among the six stations. The west control stations, with a much higher proportion of sand substrate, and the shallow trestle station, with a significant amount of medium relief bedrock and reef, had the lowest catches of whelks overall. Based on the stable nature of the population at two of the three deep stations (i.e., no significant differences in CPTH among quarters), this abundant and ubiquitous gastropod has the potential to support a small commercial fishery in the Pt. Conception area should a market be developed.

Bottom Temperature and Whelk Relative Abundance

The consistent decline in CPTH for whelks at the three stations from the winter to spring quarter may indicate movement to deeper water as temperatures declined or a lowered metabolic level with less food-seeking activity. Spring quarter was the only one in which bottom temperatures at shallow stations were lower than those at deep stations. This decline in CPTH was not observed at two of the deep stations.

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CHRONIC BRANCHITIS (HAMBURGER GILL DISEASE) OF CHANNEL CATFISH IN CALIFORNIA AND ITS POSSIBLE MYXOSPOREAN ETIOLOGY [1]

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A chronic branchitis in cultured channel catfish *Ictalurus punctatus* (Rafinesque), known also as "hamburger gill disease" or "proliferative gill disease" has occurred throughout California and the southeastern United States. A protozoan was associated with the gill lesions observed in epizootics in California. It shows ultrastructural properties consistent with those of the Myxozoa and it may represent trophozoites of *Henneguya exilis* Kudo. The disease differed from typical *H. exilis* infections because few spores were observed and the gills exhibited an unusual response characterized by severe diffuse granulomatous inflammation and epithelial hyperplasia.

Introduction

Outbreaks of chronic branchitis in channel catfish at several farms in California have occurred and a protozoan, most likely of the phylum Myxozoa, is suspected to be the etiological agent. Similar diseases have also occurred throughout fish farms in the southeastern United States, where it is referred to as "hamburger gill disease" (HGD) or "proliferative gill disease" and mortalities may reach 100% (Bowser and Conroy 1985). A microsporidan (Rodgers and Miyazake 1984), epitheliocystis organisms (MacMillan 1985), and myxosporean trophozoites, possibly belonging to the genus *Henneguya* (Bowser and Conroy 1985; Haskins, Torrans, and Lowell 1985) have all been reported to be associated with HGD. Poor water quality has also been suggested as a contributing factor, although no consistent water quality parameters have been associated with HGD (MacMillan 1984). The disease is characterized by very pale, grossly swollen and clubbed gills. Histological examination of affected fish shows a severe multifocal interlamellar proliferation of gill tissue (Bowser and Conroy 1985).

We describe here a myxosporean trophozoite and associated lesions from outbreaks of HGD in California that were submitted as diagnostic cases to the University of California, Davis fish disease laboratory. Although branchitis in fish can be caused by many different agents, we have observed this parasite in most cases of branchitis of channel catfish that we have examined.

Methods

Light and Electron Microscopy

Channel catfish from epizootics of HGD were examined for gross pathological changes and the tissues were fixed in 10% buffered formalin or Davidson's solution (Humason 1979). They were embedded in paraffin, sectioned and

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stained with either hematoxylin and eosin, Giemsa, Brown and Brenn, acid fast or periodic acid Schiff stains. Gill specimens for electron microscopy were fixed in 3% (v/v) glutaraldehyde in a phosphate buffer as described by Bullock (1978). These specimens were post fixed in OsO_4, embedded in Epon, sectioned, stained with lead citrate and uranyl acetate and observed with a Zeiss 109 electron microscope.

Virus and Bacterial Examination

The gills and visceral tissues of fish with HGD from two farms were examined for virus content by standard methods (McDaniel 1979). The brown bullhead *(Ictalurus nebulosus)* (BB) and channel catfish ovary (CCO) lines were employed. The conditions for cultivation of these cells have been described previously (Hedrick et al. 1984).

Spleen and kidney tissues of 30 affected fish were examined for bacteria using bovine blood agar, brain heart infusion and Cytophaga agar. Gills were examined in wet mounts and by Gram stains.

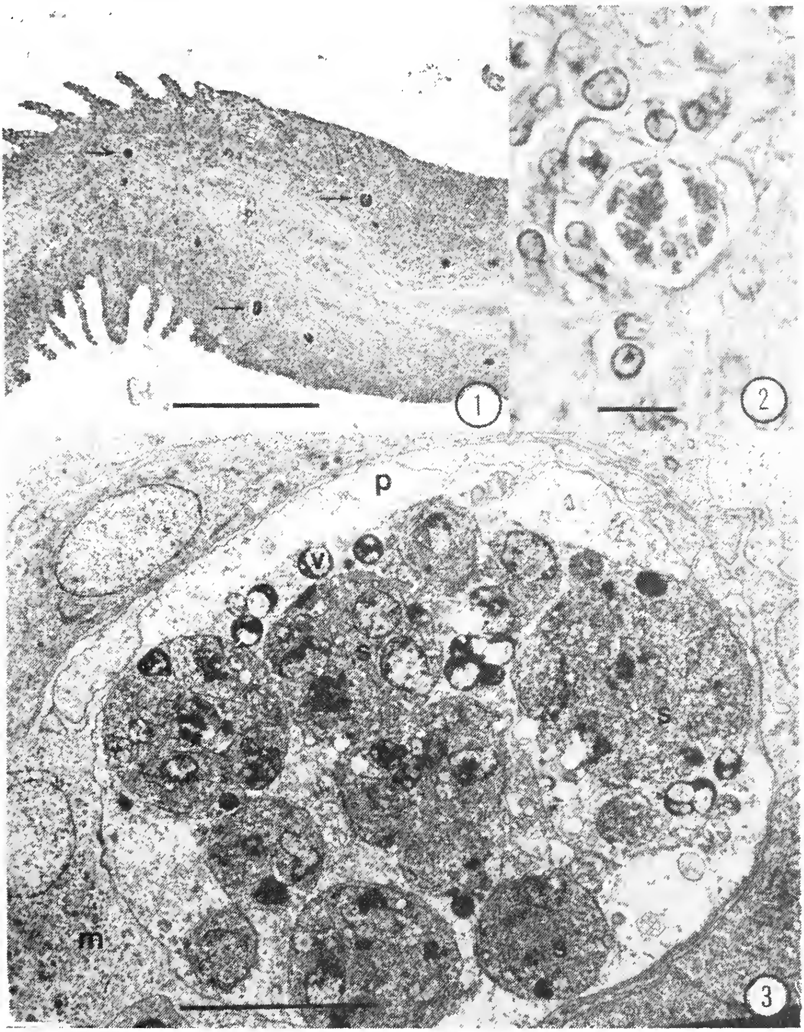
Results

Nine outbreaks of HGD were diagnosed at four farms from November 1982 through May 1984. One farm is in northern California, while the others are located in the central and southern parts of the state. The disease occurred without a clear seasonality (January, March through June, November and December) and was found in a wide temperature range (8–30°C). Affected fish were market size (approximately 0.5–1.0 kg), except for one case in which juveniles at approximately 0.1 kg were also affected. Mortalities were usually chronic and remained below 20%. However, in one case, sudden massive mortalities occurred in association with low dissolved oxygen content in the water.

Gills from all cases exhibited similar gross and histologic changes. They were extremely hypertrophied, mottled and hemorrhagic. Histologic examinations revealed severe hyperplasia of the gill epithelium, which resulted in fusion of the secondary lamellae. Diffuse or multifocal granulomatous inflammation occurred within the primary lamellae. The supporting rod was often involved and focal necrosis of the cartilage was prominent, causing twisting of the gill distal to the lesion (Figure 1). Deep throughout areas of inflammation were multicellular, basophilic protozoans with 10–30 small nuclei. Large whorls of macrophages often surrounded the parasites (Figures 1, 2). Cysts containing developed spores of *Henneguya exilis* were found in HGD affected fish at three of the four farms. These spores were detected in 11 of 35 fish examined. However, very few of these cysts were observed and when present there was little associated tissue reaction.

During this time period three additional outbreaks of branchitis not associated with the HGD parasites were diagnosed in channel catfish from California. One outbreak was due to typical interlamellar *Henneguya* infections with abundant mature spores in all affected fish. The other two cases were due presumably to waterborne toxins without the presence of gill parasites.

An examination of the multicellular protozoans (trophozoites) by electron microscopy revealed similarities with the Myxozoa. Plasmodia with distinct pinocytic vesicles were not clearly identified, but internal cells suggestive of early sporoblasts were present (Figure 3). Individual vegetative nuclei were also found in the degenerated plasmodium. Large microtubule bundles were observed in the cytoplasm adjacent to the nucleus in the sporogonic cells (Figure 4).



FIGURES 1-3. Gills of channel catfish affected with hamburger gill disease [HGD]. 1 & 2 Paraffin sections stained with H & E, 3 & 4 Electron micrographs. 1. Gill exhibiting fusion of the secondary lamellae, cartilage necrosis and protozoan cysts [arrows] associated with the granulomatous response. Bar = 300 μ. 2. Protozoan cyst surrounded by host cell macrophages. Bar = 10 μ. 3. Degenerating plasmodium [p] with sporoplasts [s] and vegetative nuclei [v], surrounded by host macrophages [m]. Bar = 10 μ.

FIGURE 4. Generative cell with microtuble bundle [t] adjacent to the nucleus [n]. Bar = 1 μ.

No pathogenic bacteria were isolated from spleens or kidneys of affected fish, and insignificant numbers of bacteria were observed on the gills in wet mounts. *Trichodina, Trichophrya* and *Costia* were occasionally seen in low numbers on some fish and they were often absent in fish with severe HGD from the same outbreak.

Discussion

Diffuse epithelial hyperplasia of the gills with fusion of the secondary lamellae is commonly associated with waterborne toxins, such as pesticides and high ammonia levels, and may also occur with external protozoan and bacterial infections (Eller 1975). However, hamburger gill disease can be differentiated from other forms of branchitis by the presence of massive mononuclear cell infiltration centered around multicellular basophilic myxosporean trophozoites and accompanying destruction of the cartilage support filaments.

MacMillan (1984) reported no obvious water quality parameters associated with HGD, and the disease in California has occurred throughout the state with no clear seasonality or water temperature regime. However, affected fish may suffer acute mortalities following a drop in dissolved oxygen content in the water. At one farm sudden death in fish with HGD occurred when oxygen levels dropped to approximately 2 ppm, while unaffected fish at the same site experienced no mortality. Similar difficulties can occur in catfish infected with intralamellar *Henneguya*. This form of *Henneguya* exhibits spore development within capillaries of gill lamellae and is usually nonpathogenic, whereas interlamellar *Henneguya* spores develop among basal cells between lamellae and can cause severe lamellar fusion (McCraren et al. 1975). Severe losses were associated with intralamellar *Henneguya* when heavily infected fish were subjected to low dissolved oxygen concentrations (Current and Janovy 1978).

The parasite described in our report shows similarities to the Myxozoa, which are ubiquitous parasites of fishes (Mitchell 1977). Multicellular sporoblasts and vegetative nuclei within a plasmodium are consistent features of the prespore stages (Mitchell 1977) and the presence of large microtubule bundles and absence of centrioles have been used to assign presporogonic protozoa to the phylum Myxozoa (Lom, Dyková and Pavlásková, 1983).

The parasites of HGD may be trophozoites of *H. exilis.* This myxosporean is commonly observed in channel catfish gills and it is pathogenic in its interlamellar form (McCraren et al. 1975). Haskins et al. (1985) found spores of *Henneguya* in fish with HGD, in addition to the trophozoites similar to those described here by light microscopy. They tentatively identified these trophozoites as the initial stages of *Henneguya.* Bowser and Conroy (1985) have also proposed that the protozoan associated with HGD is a presporogonic stage of *Henneguya.* The spores of this parasite were also found in a HGD affected fish in our study and *H. exilis* is widespread in channel catfish in California.

Bowser et al. (1985) transmitted the HGD trophozoites and the disease with mud and water from ponds experiencing *Henneguya* epizootics. However, they did not exclude the possibility that toxins from the ponds may have acted concurrently with the myxosporeans. Isolation and transmission of the parasites would clarify the etiology of HGD, but this is a difficult task. The life cycles of myxosporeans are poorly understood, controversial and few have been transmitted experimentally (Dana 1975; Uspenskaya 1978; Prihoda, 1983; Johnstone 1984; Wolf and Markiw 1984; Hamilton and Canning 1985). Attempts at direct transmission of fresh or aged *Henneguya* spores by intraperitoneal injection, intubation or external exposure in our laboratory have been unsuccessful.

The severe inflammatory response to the HGD parasite differs remarkably from that associated with *H. exilis* (Duhamel et al. 1986) and other gill myxosporeans. Although the interlamellar form of *H. exilis* induces hyperplasia and inflammation (McCraren et al. 1975; Current and Janovy 1978; Smith and Inslee 1980), numerous spores are observed and the inflammation is closely associated with the parasites. Usually a significant inflammatory response does not occur until spores develop (Dyková and Lom 1978) and myxosporean trophozoites may escape host defenses by mimicking host antigens (Pauley 1974; Halliday 1974). An exception is the PKX parasite, which causes proliferative kidney disease (PKD) of salmonids. With PKD, a severe, diffuse, renal interstitial hyperplasia due to mononuclear cell proliferation is often associated with very few parasites (Clifton-Hadley, Bucke and Richards 1984) and this protozoan represents a presporogonic stage of an unidentified myxosporean (Kent and Hedrick 1985a,b).

A microsporidan and epitheliocystis organisms have been reported to be associated with HGD in the southeastern United States (Rogers and Miyazake 1984; MacMillan 1985), but they were not detected in our study. Possibly the branchitis coined "hamburger gill disease" actually represents more than one disease. Because chronic branchitis in catfish may be caused by several agents, histological sections are needed to differentiate HGD from other gill lesions. Therefore, to avoid confusion, "hamburger gill disease" should be used only when referring to the chronic branchitis associated with the myxosporean trophozoites.

No effective drugs have been developed to treat myxosporean diseases and they are usually controlled by husbandry modifications. However, Haskins et al. (1985) found that formalin at 25 ppm reduced mortalities associated with HGD when applied during the early stages of the infection. When applied in the more advanced stages it increased mortalities by further compromising the gill function. They concluded that this treatment may destroy the preinfective stages of the parasite or an unknown intermediate host. Myxosporeans can be eradicated from ponds by drying and disinfection with calcium oxide (Hoffman and Hoffman 1972). If proven to be effective, catfish farmers could utilize disinfection of ponds between growing seasons to minimize the intensity of HGD infections. Handling and low oxygen levels compound the effects of the disease. Therefore, ponds with affected fish should be aerated and fish should not be handled or transported when gills are heavily involved. If a feral non-ictalurid is the reservoir host, then it should be identified and eradicated from the ponds if possible.

The myxosporean trophozoite described here is most likely the etiological agent of HGD, at least in California. However, absolute confirmation of the cause of HGD and the precise taxonomic status of the trophozoites can only be determined by isolation and subsequent transmission of *Henneguya* spores or the HGD trophozoites.

Acknowledgment

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COMPARATIVE CATCHES OF OCEAN SPORT-CAUGHT SALMON USING BARBED AND BARBLESS HOOKS AND ESTIMATED 1984 SAN FRANCISCO BAY AREA CHARTERBOAT SHAKER CATCH [1]

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Sport-caught chinook, *Oncorhynchus tshawytscha,* and coho, *O. kisutch,* salmon were sampled aboard charterboats operating off Eureka and San Francisco during the 1984 salmon season to compare the catch efficiencies of barbed and barbless hooks and estimate the sublegal salmon catch. A total of 679 and 712 chinook was caught on barbed and barbless hooks, respectively, while 53 and 55 coho were caught on barbed and barbless hooks, respectively. Barbless hooks were at least as efficient as barbed hooks at catching all sizes of salmon, whether the hooks used were single, duranickel trolling hooks or herring/anchovy slip rigs.

The estimated 1984 chinook sublegal catch by the San Francisco Bay area charterboat fishery was 18,200, with an estimated mortality of about 5,500 fish. The largest numbers of sublegals were caught during May and June, whereas the highest percentages of sublegal fish in the catch were in February and March.

INTRODUCTION

In an effort to reduce adverse impacts on sublegal or out-of-season salmon (shakers), the California Fish and Game Commission passed a regulation in 1984 requiring sport anglers to use single, barbless hooks for ocean salmon fishing. The minimum size limit for sport-caught ocean salmon off California in 1984 was 50.8 cm TL. According to some salmon charterboat operators, the use of barbless hooks reduced fish handling time and the benefits seemed positive toward reducing stress to the fish. Physical damage to the fish was also reported to be less severe. A previous study on the Oregon commercial troll salmon fishery indicated that barbless hooks would reduce mortality of salmon hooked and released, particularly coho, but would not significantly reduce the overall shaker problem (Butler and Loeffel 1972).

Wright (1970), in a literature review, concluded that the mortality rate for commercial ocean troll-caught chinook and coho salmon shakers is probably between 15 and 45% and that estimates above 30% are questionable. He also reported that data on sport-caught salmon hooking mortality are limited, and that the hooking mortality rate for this fishery is probably lower than the rate for the commercial fishery. Other detrimental effects from hook and release of salmon stem from physical injury which can reduce fish growth and condition (Fulmer and Ridenhour 1967).

This study was designed to (1) compare the catches of sport-caught salmon off California by anglers using single barbed and barbless hooks, and (2) determine the sublegal salmon sport catch for the San Francisco Bay area charterboat fleet.

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MATERIALS AND METHODS

Sampling was conducted aboard charterboats operating out of the San Francisco Bay area and King Salmon (near Eureka) (Figure 1). Sampling off San Francisco took place twice per week throughout the 1984 season (February 18–November 18). On each sampling day, a sampler recorded the daie, vessel number, number of passengers, number and species of all legal and sublegal salmon landed, and hook type used (barbed or barbless). All salmon were measured to the nearest 0.1 cm FL, except when large numbers of sublegals were caught simultaneously. In these situations, all sublegals were enumerated by species, and length and hook type data were taken randomly from as many sublegal fish as possible. Hooks used off San Francisco were single, duranickel salmon trolling hooks (Miller brand) (Figure 2), with hook shanks ranging from 7.6 to 12.7 cm in length and hook sizes ranging from 3/0 to 6/0. The shank was bent slightly to give the bait more action. Hook size selection was based on bait size. Northern anchovy, *Engraulis mordax,* was used for bait throughout the study. Prior to fishing, all hooks were baited and randomly mixed together in a bait tray; one-half of the hooks were barbed and the other half were made barbless by pinching the barb flush with pliers. A small bump remained on the barbless hook, but the sharp edge of the barb was smooth. Anglers were free to choose which baited hook they wished to use. On three occasions, data were gathered to determine whether anglers had any hook preference. Of the hooks returned to the bait tray, 49% were barbed and 51% were barbless (Table 1), indicating no significant selectivity ($X^2 = 0.34$). Anglers appeared to be more concerned with the size and appearance of the bait itself rather than the hook type. All salmon caught on other terminal gear (e.g., artificial lures) were omitted from the catch rate by hook type analysis, but were included in estimating the shaker catch. Each baited hook was attached to an approximately 2-m long monofilament leader which was attached to a sinker release holding a 1.1 to 1.4 kg ball sinker (Figure 3). Conventional rod and reel gear was used to fish the main fishing line.

Sampling off Eureka occurred during 15 boat trips between July 17 and August 8. The main purpose for sampling off northern California was to increase the sample size for coho salmon, since few coho are caught off San Francisco and coho are normally abundant off Eureka. The terminal gear used off Eureka is commonly called a herring/anchovy slip rig (Figure 2), which was comprised of two single, stainless steel baitholder hooks (Mustad brand), with turned up ball eyes and Siwash bend. A 5/0 hook was fixed to the end of the monofilament leader, while a 2/0 sliding hook was tied above the fixed hook and adjusted to fit the size of the bait. Each hook rig was baited with an anchovy and trolled behind a "Deep Six" diving plane (Figure 3). When an angler needed a fresh bait, he was given a new bait, but retained the same rigging throughout the trip. If the rigging were lost, it was replaced with an identical one. Barbed and barbless hook rigs were used in alternating order around the boat perimeter. Otherwise, all sampling methods were identical to those used off San Francisco.

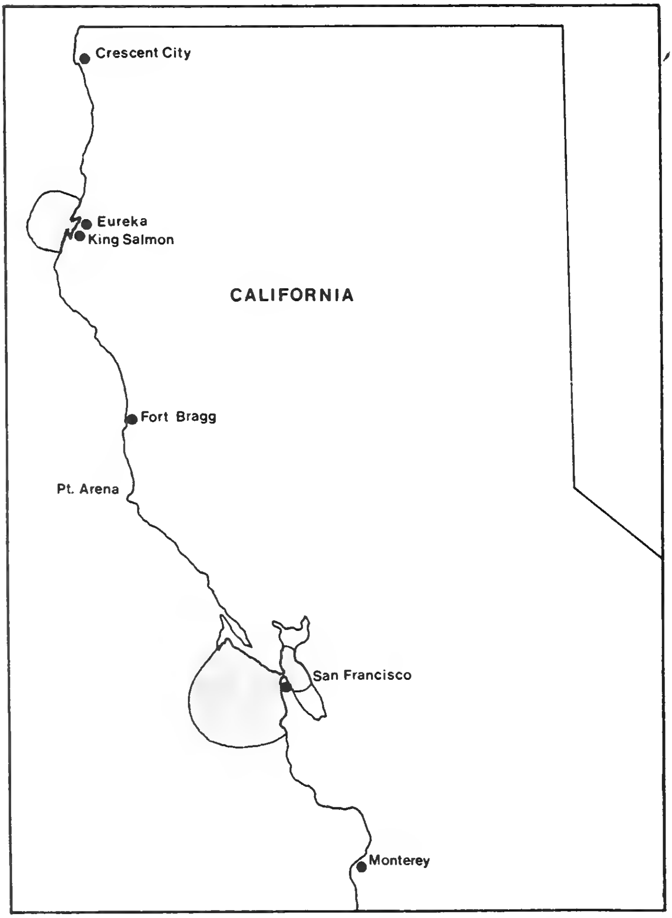

FIGURE 1. Map of Central and Northern California showing study sampling areas (shaded).

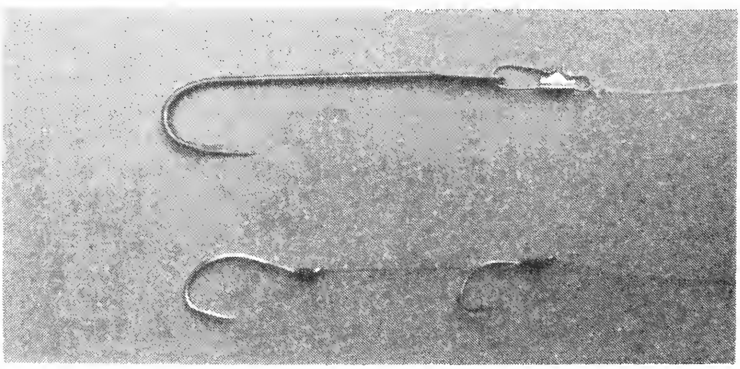

FIGURE 2. Single duranickel salmon trolling hook (top) and herring/anchovy slip rig (bottom). *Photograph by author (January 1985).*

TABLE 1. Comparison of Hook Types Selected by San Francisco Bay Area Salmon Charterboat Anglers.

Date of sample	*Hook type used*		*Total*
	Barbed	*Barbless*	
18 Feb 84	29	28	57
5 May 84	106	119	225
9 Sept 84	67	67	134
Total	202	214	416

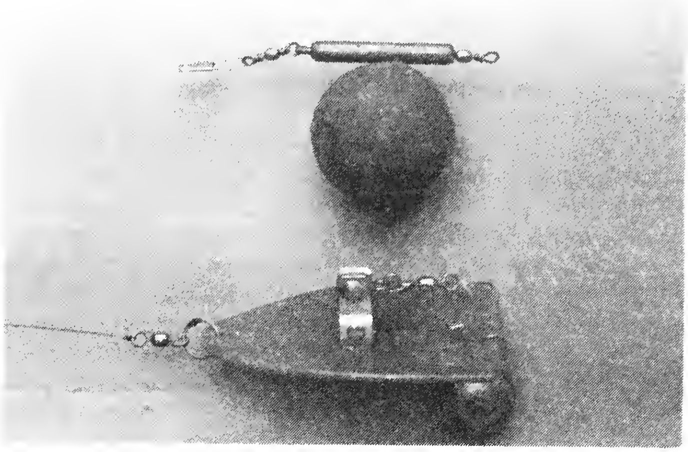

FIGURE 3. Sinker release with 1.4 kg ball sinker (top) and Deep Six diving plane (bottom). *Photograph by author (January 1985).*

Results and Discussion

There were no statistically significant differences in the catches of chinook or coho salmon using barbed or barbless hooks for any size class examined, except for sublegal chinook off Eureka, where 28 were caught using barbless hooks compared to 12 caught using barbed hooks (Table 2). The sample size of the fish, however, was very small ($n = 40$). It was expected that barbless hooks might catch fewer coho than barbed hooks because coho are more active fighters than chinook and would more likely throw a barbless hook. The data, however, indicated no significant difference between the two hook types for either species.

Butler and Loeffel (1972) conducted a barbless hook study on salmon caught off Oregon using commercial troll gear and found that 51.3, 50.7, and 52% of the legal size chinook, sublegal chinook, and legal coho, respectively, were caught using barbed hooks. Only coho were caught in significantly higher numbers ($P < 0.05$). Richard Hallock of the California Department of Fish and Game compared the effectiveness of barbless hooks in a 1950 study off northern California using commercial gear and found that 56% of the chinook and 57% of the coho were caught on barbless hooks (Table 3). He could not explain why more salmon were caught on barbless hooks, but concluded that barbless hooks were at least as efficient as barbed hooks in catching chinook or coho salmon on commercial gear.

TABLE 2. Comparisons of Eureka and San Francisco Chinook and Coho Charterboat Catches by Sport Anglers Using Barbed and Barbless Hooks (Numbers of Fish)[1].

Port	Species	Hook type	Fork length < 46.5 cm	Chi^2	Fork length 46.5–60.9 cm	Chi^2	Fork length > 60.9 cm	Chi^2	All sizes combined	Chi^2
Eureka	CHINOOK	Barbed	12	6.40 *	18	1.14	14	.04	44	4.40 *
		Barbless	28		25		13		66	
	Subtotals		40		43		27		110	
	COHO	Barbed	1	[2]	3	[2]	40	.05	44	.17
		Barbless	3		7		38		48	
	Subtotals		4		10		78		92	
San Francisco	CHINOOK	Barbed	150	.08	381	.07	104	.17	635	.09
		Barbless	145		391		110		646	
	Subtotals		295		772		214		1,281	
	COHO	Barbed	1	[2]	2	[2]	6	[2]	9	[2]
		Barbless	0		1		6		7	
	Subtotals		1		3		12		16	
Eureka and San Francisco combined	CHINOOK	Barbed	162	.36	399	.36	118	.10	679	.78
		Barbless	173		416		123		712	
	Subtotals		335		815		241		1,391	
	COHO	Barbed	2	[2]	5	[2]	46	.04	53	.04
		Barbless	3		8		44		55	
	Subtotals		5		13		90		108	
TOTALS			340		828		331		1,499	

* Difference is significant at 5% level.
[1] Does not include unsampled sublegals (FL < 46.5 cm) or salmon caught on artificial lures.
[2] Inadequate sample size.

TABLE 3. Comparison of Chinook and Coho Salmon Catches off Northern California by Hook Type Using Commercial Troll Gear [1].

Species	*Hook type*	*Catch*
Chinook	Barbed	91
	Barbless	116
Subtotal		207
Coho	Barbed	26
	Barbless	35
Subtotal		61
TOTAL		268

[1] Unpublished data collected on the "N. B. Scofield" by Richard Hallock, California Department of Fish and Game, from May 17–July 8, 1950. A total of 93 fishing hours was expended using fixed, power driven gurdies to fish the main troll lines. Terminal gear used was #6-½ McMahon brass spoons with 7/0 single hooks. Fishing area was between Fort Bragg and Crescent City.

It should be noted that all catch comparisons between barbed and barbless hooks during this study relate only to sport salmon gear fished off charterboats and may not apply to catches made using commercial troll gear from commercial vessels or sport gear from private skiffs. Since charterboats generally continue trolling after a fish is hooked, constant tension is maintained on the fishing line, which may aid in preventing the fish from throwing the hook. Some private skiff sport anglers do not follow this practice, as many salmon are hooked while drift fishing and some skiff anglers discontinue trolling from the time a fish is hooked until it is landed.

In this study, the mean length of 679 chinook caught on barbed hooks and 712 chinook caught on barbless hooks was identical at 52.4 cm FL. The mean length of 53 coho caught on barbed hooks was 65.1 cm FL, while the mean length of 55 coho caught on barbless hooks was 64.1 cm FL. The 1.0-cm difference in coho length was not statistically significant ($P > 0.5$).

Of the 1,375 chinook sampled off the San Francisco Bay area, 354 (25.7%) were sublegal (Table 4). Multiplying the preliminary 1984 San Francisco charterboat monthly chinook landings by the sublegal to legal ratios for respective months, and summing the products, resulted in a total sublegal catch estimate of 18,203 salmon, or 21% of the total charterboat catch (legal + sublegal). The largest numbers of sublegals were caught during May and June with a minor peak in September (Figure 4). The highest monthly percentages of sublegal chinook in the total monthly catches occurred in February and March with a minor peak in September (Figure 5).

Based on coded-wire-tag data, about 41, 57, and 2% of the chinook landed in the San Francisco sportfishery are into their second, third, and fourth years of ocean life, respectively (Pacific Fishery Management Council 1984). The high percentage of sublegals in the catch during the winter and spring months was probably made up primarily of fish entering their third life which are large enough to be vulnerable to the fishing gear, but below the minimum size. As the season progressed, these fish grew rapidly and increased numbers were recruited to the legal harvest. In the fall, those salmon completing their second year of ocean life became large enough to be vulnerable to sport gear and began showing up in the catch. It should be noted that sublegal catch patterns may

TABLE 4. Chinook Sample Statistics for the 1984 San Francisco Charterboat Sport Fishery.

Item	*Month*										*Season total*
	FEB	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	
Sublegals (< 46.5 cm) sampled	21	59	62	97	59	19	11	23	3	0	354
Legals (≥ 46.5 cm) sampled	10	27	97	124	197	210	210	93	17	36	1,021
Sublegal to legal ratio	2.10	2.19	.64	.78	.30	.09	.05	.25	.18	0	.35 [1]
Number of sampling trips	2	6	7	7	10	7	10	9	8	4	70

[1] Unweighed. The seasonal sublegal to legal ratio weighted by monthly catches is .26.

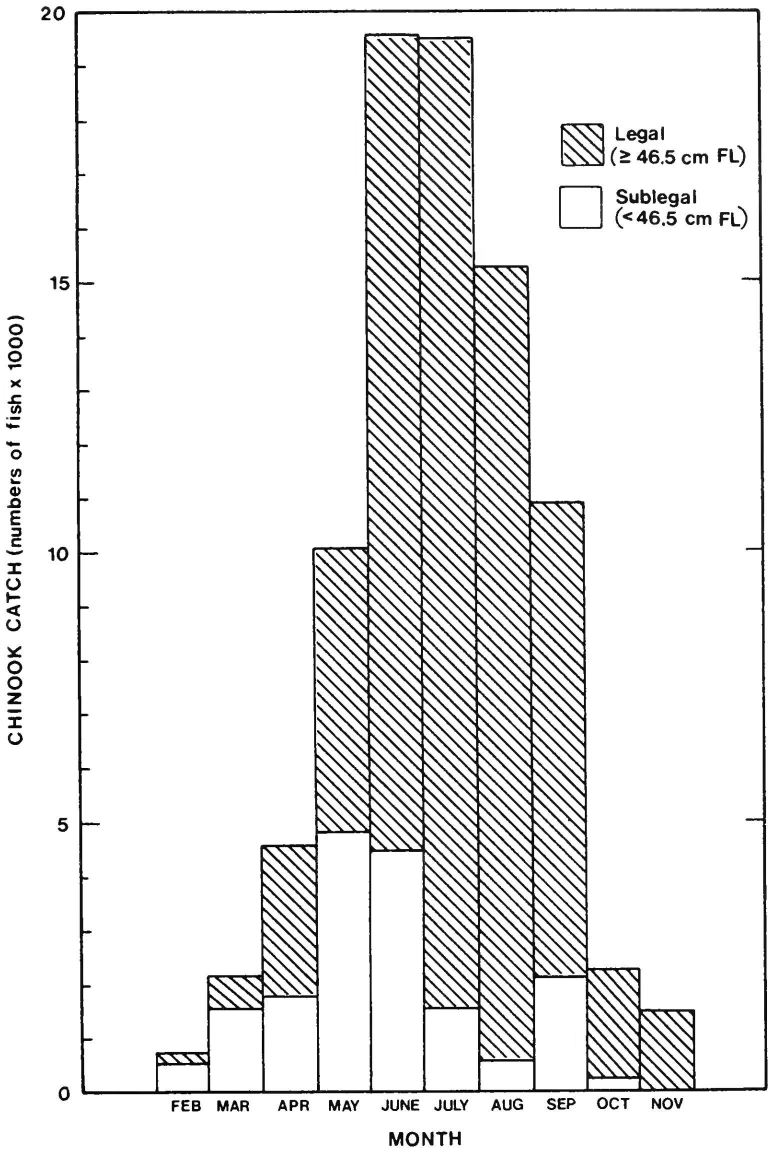

FIGURE 4. Estimated 1984 San Francisco Bay area charterboat chinook salmon catch by month.

have been atypical during 1984, since these fish had reduced growth rates during 1983 when warm water (El Niño) conditions prevailed (Pacific Fishery Management Council 1984). Thus, recruitment to the sportfishery may have been delayed.

Assuming a shaker hooking mortality rate of 30% (Wright 1970), the estimated 1984 shaker mortality was about 5,500 for the San Francisco charterboat fleet, which is only 2.3% of the total 1984 San Francisco sport and commercial landing of 237,500 legal-sized fish. The actual shaker mortality rate, however, was probably below 30%, since Wright's figure is based on a review of studies involving commercial troll gear. Shaker losses off charterboats are probably lower than off commercial vessels because sublegal salmon are landed sooner after hooking, and sport-caught sublegals are generally smaller and easier to handle than commercially-caught sublegals. The chinook and coho minimum size limits in the ocean commercial fishery are 66 cm TL and 55.9 cm TL, respectively.

Of the 16 coho sampled off the San Francisco Bay area, only one (6%) was sublegal (Table 4). Because of the small sample size, no coho shaker catch estimate was made. However, because the percentage of coho shakers for combined samples taken at San Francisco and Eureka was only 5% (5 shakers for 108 coho observed caught), coho shaker catches do not appear to be a major problem in the California sportfishery.

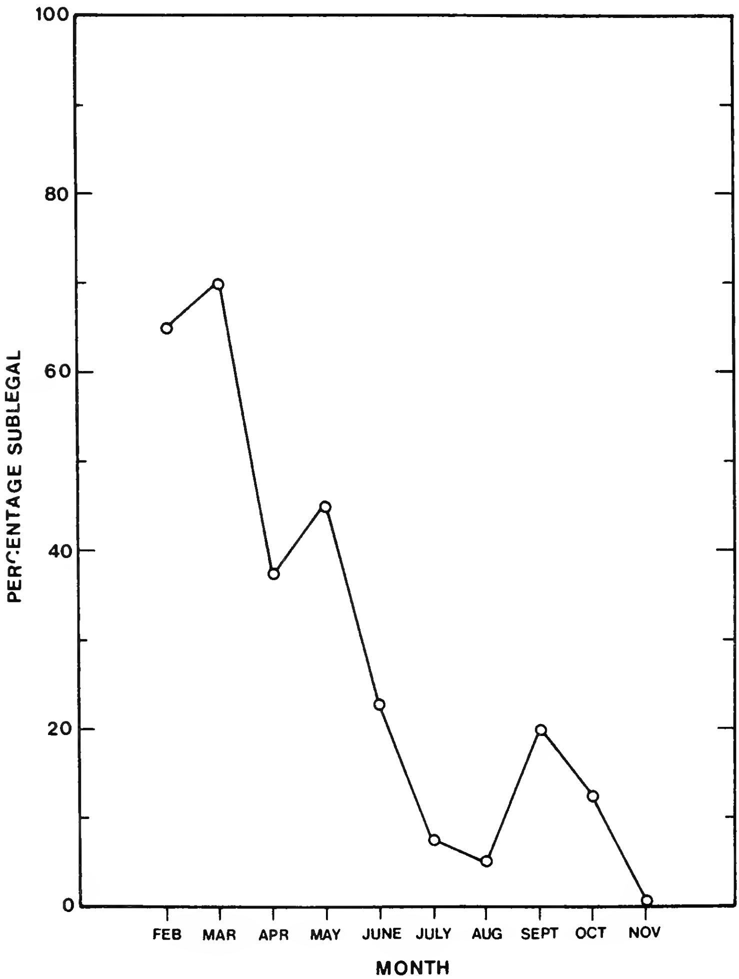

FIGURE 5. Percentage sublegals in the estimated 1984 San Francisco Bay area chinook salmon catch by month.

Of the 110 chinook sampled off Eureka during 1984, 40 (36%) were sublegal, whereas only 4 of 92 (4%) coho sampled were sublegal. The small sample sizes preclude comparisons with shaker catches off San Francisco.

From onboard observations, barbless hooks appeared to substantially reduce the handling time required to remove hooks from sublegal salmon and resulted in less physical injury. These observations applied to both the single trolling hook and the sliding hook rig.

One concern with the barbless hook regulation is that it applies to all methods of take. During the summer months, live bait charterboat anglers out of San Francisco Bay area ports often catch salmon while targeting on striped bass, *Morone saxatilis*. In this fishery, barbed hooks are used to retain live anchovies on the hooks while fishing. Skiff anglers also capture and use live bait with barbed hooks while drift fishing for salmon, and anglers fishing for rockfish and halibut with barbed hooks occasionally catch salmon. The total salmon catch in these fisheries is unknown, but is believed to be a minor portion of the total sportcatch.

CONCLUSIONS

From this study, I concluded that there is no significant difference between ocean catch rates of chinook salmon caught off California charterboats by sport anglers using barbed or barbless hooks. Barbless hooks are at least as efficient at catching chinook as barbed hooks, whether the Miller duranickel single trolling hook or the herring/anchovy sliding rig is used. The same conclusion could be drawn for coho, although additional coho data would be desirable, as would further study of skiff fishing methods for coho and chinook.

Because the handling time required to remove hooks from sublegal salmon appeared to be reduced when barbless hooks were used, and there appeared to be less physical damage to fish caught with barbless hooks, it is likely that mortalities were also reduced.

Assuming a 30% shaker mortality rate, the estimated maximum chinook shaker mortality for the San Francisco charterboat fleet during 1984 was 5,500 and is insignificant when compared to the total San Francisco area chinook sport and commercial harvest of 237,500 salmon. The highest shaker catches during the study occurred in May and June and the largest sublegal percentage in the catch was in February and March. The observed percentage of coho shakers in the charterboat catch was very low (5%), indicating that there is no significant coho shaker problem in the California sportfishery.

The current barbless hook regulation applies to all methods of take. Further study should be made on non-troll ocean salmon sportfisheries to estimate shaker catches and determine the effects of barbless hook use on the catch rates of salmon and other fish species landed in these fisheries.

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BIOLOGICAL NOTES ON THE PACIFIC SLEEPER SHARK, SOMNIOSUS PACIFICUS (CHONDRICHTHYES: SQUALIDAE) [1]

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Information was obtained on the Pacific sleeper shark, *Somniosus pacificus* Bigelow and Schroeder, 1944, along the California coast from fishermen who caught specimens incidentally in sablefish traps and trawls. Morphometric and tooth-count data were taken from several specimens. An estimate of fecundity was based on one specimen with 372 yellow, vascularized, ovarian eggs. The approximate size at maturity was determined using gonadal development and a length-weight curve. Pacific sleeper sharks are considered sluggish, bottom-dwelling, cephalopod and fish feeders, yet they may occasionally consume fast swimming epipelagic fish.

INTRODUCTION

The Pacific sleeper shark, *Somniosus pacificus* Bigelow and Schroeder, 1944, is considered an uncommon deep water species which ranges from Japan and the Bering Sea to Baja California (Gotshall and Jow 1965, Miller and Lea 1972, Anderson, Cailliet, and Antrim 1979, Compagno 1984). Pacific sleeper sharks are large, reputed to reach over 7 m total length (TL), and thought to be sluggish (Castro 1983, Compagno 1984).

Due to their large size, deep habitat, and lack of commercial importance, the Pacific sleeper shark is poorly known biologically. Most specimens that have been obtained have come from the incidental catch of commercial fishermen. Anderson et al. (1979) reported on six Pacific sleeper sharks ranging from 92 to 142 cm TL landed at Moss Landing by sablefish trappers. One specimen, estimated over 4.5 m TL, was brought to the surface in northern Monterey Bay but could not be landed (Anderson et al. 1979). Gotshall and Jow (1965) reported on two females taken off Trinidad, California, and Phillips (1953) reported on a large male (397 cm TL) caught off Fort Bragg, California. Osada and Cailliet (1975) stated that Pacific sleeper sharks were commonly caught by sablefish trappers in Monterey Bay.

We present information here to update the biological knowledge on this shark.

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MATERIALS AND METHODS

Pacific sleeper sharks were obtained from commercial fishermen who caught them incidentally in sablefish traps and trawls. All sharks caught were taken from California waters. Additional Pacific sleeper shark data was compiled from specimens and records at the California Academy of Sciences (CAS), California Department of Fish and Game (CDFG), Natural History Museum of Los Angeles County (LACM), Moss Landing Marine Laboratories (MLML), Stanford University (SU), and from the literature (Scofield 1920, Phillips 1953, Bright 1959, Tanaka, Yano, and Ichihara 1982).

Length and weight information for females was fitted to a polynomial curve. This information was combined with gonad development to estimate approximate size at maturity. Since no females with developing embryos have been reported, fecundity in the Pacific sleeper shark can only be estimated by the number of vascularized eggs present.

The stomachs of freshly caught and museum specimens were dissected and the contents identified to the lowest possible taxon.

RESULTS AND DISCUSSION

We obtained information on 32 Pacific sleeper sharks; except for two male specimens all were female or the sex was unknown. These sharks measured between 74 and 430 cm TL. Morphometric data for three specimens are listed in Table 1. Tooth counts were taken from 16 specimens (Table 2). Our largest specimen, 430 cm TL, had only one large egg in her uterus and may have lost others while being lifted from the water. The next longest specimens, 408 and 419 cm TL, contained no eggs, while a 401 cm TL specimen was found to contain 372 large yellow vascularized, ovarian eggs. An additional 20 to 30 eggs were lost when the specimen was dissected. Of these unfertilized eggs 324 ranged from 24 to 50 mm in diameter (Figure 1). The remaining 48 eggs were broken and we were unable to get accurate measurements. Several thousand small white eggs ($<$ 10 mm diameter) were also observed in the ovaries. Gotshall and Jow (1965) previously reported a 366 cm TL specimen contained 300 unfertilized eggs ranging from 45 to 58 mm in diameter. It is uncertain how many of these ovarian eggs are shed into the oviduct at a time. Most squaloid sharks for which information is available have less than 24 embryos (Castro 1983, Compagno 1984). Bjerkan (1957) and Koefoed (1957) reported a litter of at least ten fetuses in one uterus of a 5 m Greenland shark, *Somniosus microcephalus*. One of these fetuses was apparently full-term at 38 cm, with resorbed yolk-sac, erupted denticles, and visible teeth.

The smallest free swimming Pacific sleeper sharks recorded were two 74 cm TL females. One was taken 25 miles WNW of San Nicholas Island at a depth of 1300 m (LACM 37706-1). The other was captured by a trawler in Monterey Bay at a depth of 390 m. The latter specimen had an umbilical scar which measured one millimeter in length.

Based on our length-weight curve of 15 specimens, and the smallest adult female Pacific sleeper shark known (Gotshall and Jow 1965) we estimate that maturity occurs at about 370 cm TL (Figure 2). Our largest measured Pacific sleeper shark, 430 cm TL, 545.5 kg, weighed considerably less than a 401 cm TL

TABLE 1. Morphometric Data for Three *Somniosus pacificus* (as Percent TL).

Measurement	Catalog Number *LJVC-0405*	*LJVC-0418*	*CAS-33586*
Total Length (mm)	1,060.0	2,113.0	4,300.0
Precaudal length	80.2	78.6	80.9
Preorbital length	8.0	9.5	6.4
Prenarial length	3.3	3.3	3.0
Preoral length	10.7	9.5	7.4
Prebranchial length	19.1	22.2	19.8
Head length	25.5	30.8	27.2
Snout-vent length	67.0	64.8	67.8
Predorsal 1 length	47.2	44.5	47.2
Interdorsal length	14.6	15.9	14.9
Dorsal-caudal length	7.5	6.5	9.3
Pectoral-pelvic length	31.1	27.4	31.5
Pelvic-caudal length	10.4	10.4	11.6
Eye length	1.9	1.2	1.3
Eye height	1.4	1.1	0.7
Nostril width	2.5	2.1	1.9
Internarial width	4.1	3.5	3.5
Spiracle length	0.7	0.8	1.2
Eye-spiracle length	2.8	3.1	2.3
Mouth length	2.8	1.7	–
Mouth width	9.2	8.3	6.5
Upper labial furrow	2.1	1.4	2.1
Lower labial furrow	1.6	1.7	1.5
1st gill slit height	3.9	3.2	2.8
5th gill slit height	4.1	4.0	3.3
Head height	4.7	10.9	9.3
Head width	11.8	11.1	9.1
Caudal peduncle height	5.2	5.0	5.0
Caudal peduncle width	3.8	4.2	4.4
Pectoral length	10.5	10.4	10.8
Pectoral anterior margin	12.0	11.6	12.4
Pectoral base	7.2	6.1	8.0
Pectoral inner margin	4.7	4.3	3.8
Pelvic length	10.5	9.5	9.3
Pelvic anterior margin	7.1	4.7	7.0
Pelvic base	7.4	5.7	5.8
Pelvic inner margin	4.4	3.8	4.2
First dorsal anterior margin	8.0	6.2	5.0
First dorsal base	7.5	6.4	4.2
First dorsal height	2.8	2.8	3.0
First dorsal inner margin	4.9	4.3	4.3
Second dorsal anterior margin	6.1	4.5	4.4
Second dorsal base	7.1	5.9	5.3
Second dorsal height	3.3	2.6	2.8
Second dorsal inner margin	5.7	3.9	4.0
Dorsal caudal margin	18.9	19.4	18.1
Preventral caudal margin	12.7	14.2	12.7
Lower postventral caudal margin	4.8	7.3	5.3
Upper postventral caudal margin	5.7	5.4	8.8
Subterminal caudal margin	2.2	–	1.5
Terminal caudal margin	5.8	–	7.9
Terminal lobe	7.1	–	8.1

TABLE 2. Tooth counts for 16 *Somniosus pacificus*.

Cat. no.	*Sex*	*TL (cm)*	*Tooth Counts* upper	*Tooth Counts* lower
MLML 4	F im.	74.0	17-0-16	27-0-28
CAS 38917	F im.	87.7	16-0-17	28-0-26
CDFG uncat.	F im.	92.8	10-0-12	29-0-27
LJVC 0405	F im.	106.0	21-1-20	30-0-28
CAS 27084	F im.	114.0	16-1-17	28-0-25
CAS n.a. [1]	—im.	130.0	–	27-0-28
CDFG uncat.	F im.	131.5	19-1-20	23-0-25
LJVC 0381	F im.	192.0	20-0-22	29-0-28
SU 69048 [2]	–	210.0	22-1-21	27-0-29
Tanaka et al. (1982)	F im.	268.0	20-0-21	28-0-28
CAS 27082	F ad.	366.0	–	26-0-27
LJVC 0482	F ad.	401.0	25-0-23	31-0-29
CDFG uncat.	F ad.	419.0	18-0-18	27-0-27
CAS 33586	F ad.	430.0	17-0-18	26-0-27
LACM F245	–	–	–	31-0-27
MLML 2	–	–	23-0-22	– –0-15+

[1] Jaws are not available
[2] Jaws are now at CAS

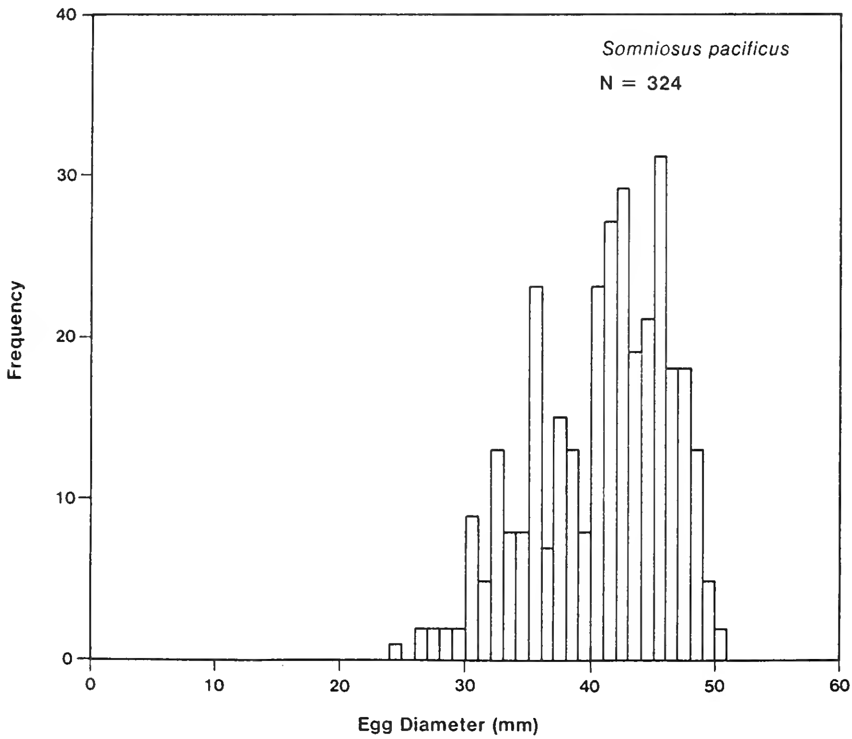

FIGURE 1. Size-frequency histogram for 324 eggs taken from an adult female *Somniosus pacificus* LJVC 0482, 401.0 cm TL.

specimen which is believed to be the heaviest recorded individual, weighing 888 + kg. The weight of this specimen is underestimated since its weight exceeded the scale's maximum capacity of 888 kg. We are unable to explain the weight discrepancy between the 401 cm TL and 430 cm TL specimens. The 430 cm TL specimen was apparently mature, but may have spontaneously aborted her eggs during capture or may even had recently given birth, which might account for the reduced ovaries and low weight. Isaacs and Schwartzlose (1975) mention larger specimens photographed in deep water off southern California and Baja California estimated at 5 to 8 m long.

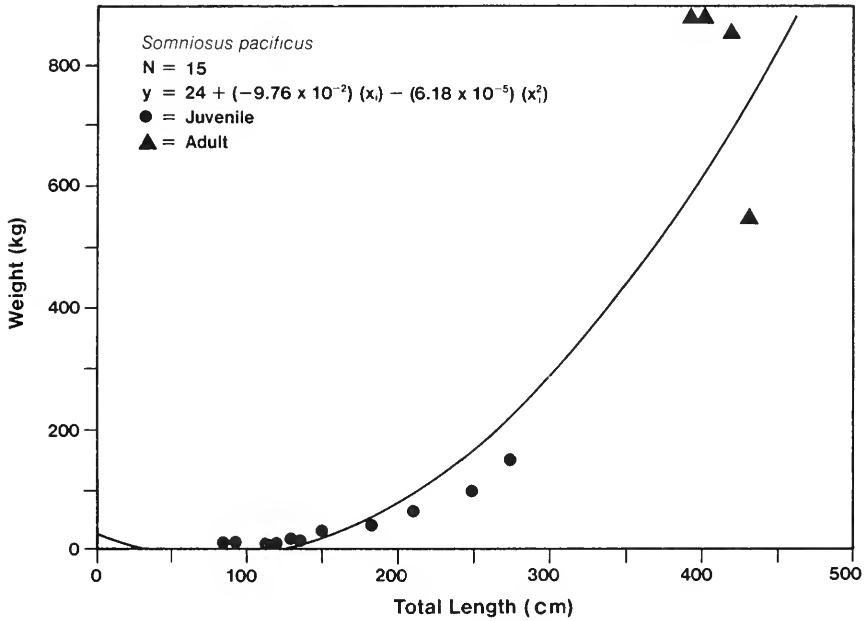

FIGURE 2. Length-weight relationship for 15 female *Somniosus pacificus*.

Data on male Pacific sleeper sharks is limited since only two specimens were recorded. One was an immature specimen, 163 cm TL, that washed ashore at a Monterey beach (R.N. Lea, Calif. Dept. Fish and Game, pers. comm.). This particular individual had a gaff wound to its head indicating that it probably had been discarded by a fisherman. The only published record of a male Pacific sleeper shark was an adult, 397 cm TL, reported by Phillips (1953).

Prey items were identified from the stomach contents of seven Pacific sleeper sharks. Several beaks of the cephalopod, *Octopoteuthis deletron,* were found in a 87.7 cm TL specimen; the gut remains of four other specimens contained unidentified cephalopod beaks. A 131.5 cm TL specimen contained two partially digested shortspine thornyheads, *Sebastolobus alascanus*. The remains of two albacore, *Thunnus alalunga*, were found in the stomach of a 401 cm TL specimen. Pacific sleeper sharks are generally considered to be bottom dwelling feeders on cephalopods and fishes. However, the occurrence of a fast swimming epipelagic fish in the stomach of a Pacific sleeper shark seems unusual as these sharks are generally considered sluggish bottom dwellers. It is possible that these unusual prey items were lost to trollers and sank, but there was no evidence of fishing tackle observed on the albacore. Another possibility may be that these sharks come off the bottom to feed and their slate gray to brownish color make them cryptically invisible to their intended prey. Moss (1981) noted that cryptic coloration in apparently lethargic sharks may explain the presence in their stomachs of fast swimming tuna and billfish. Gotshall and Jow (1965) reported finding the remains of three king salmon, *Oncorhynchus tshawytscha,* in a Pacific sleeper shark. The presence of harbor seal, *Phoca vitulina,* remains was reported by Bright (1959) in a Pacific sleeper shark. Phocid seals are a common food item for the Greenland shark (Bigelow and Schroeder 1948, Compagno 1984).

The Pacific sleeper shark in California is a deep-living, bottom-dweller known to occur to at least 2000 m; a depth at which they appear to be quite abundant at off southern California and Baja California (Isaacs and Schwartzlose 1975). The specimens for this study, except for the one beach cast, were taken between 260 and 1300 m in depth. In the northern part of their range they may occur in extremely shallow water, at the surface, and even intertidally (Bright 1959). In the southern portion of their range these sharks are found in progressively deeper water (Eschmeyer, Herald, and Hammann 1983, Compagno 1984).

ACKNOWLEDGEMENTS

We would like to thank the following persons for their time and assistance. L. Ludahl (commerical fishermen) for obtaining several specimens. B. Welton (Cheveron Oil Field Research Co., Bakersfield, California), W. Freihofer (CAS), K. Karpov (CDFG), J. Kwiecien (CDFG), and R. Prill (commercial fishermen) for obtaining and helping to dissect specimens. The following persons provided specimens and data from their respective institutions, M.E. Anderson (CAS), K. Yudin (CAS), R.N. Lea (CDFG), J. Seigel (LACM), and G. Cailliet (MLML). M. Kittridge illustrated the figures. Special thanks to G. Cailliet for reviewing the manuscript.

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NOTES

ON THE SECOND RECORD OF *BARBOURISIA RUFA,* THE VELVET WHALEFISH, FROM CALIFORNIA

In a paper titled "The velvet whalefish, *Barbourisia rufa,* added to California's marine fauna . . ." Fitch (1979) reported on a "freezer" specimen of *Barbourisia* found at Eureka Fisheries in Crescent City in 1974. The fish was without corresponding catch and locality information but it was assumed to have been taken off California. However, as with all specimens which lack collection data, the provenance of this velvet whalefish must remain conjectural. Recently, another velvet whalefish was taken off California and precise capture data were obtained. Due to the rarity of the species and the uncertainty concerning the details of capture of the Crescent City whalefish, I report herein on a second specimen.

On 24–25 January 1985, a velvet whalefish measuring 305 mm SL was captured just south of Bodega submarine canyon (lat 38 11.1′ N, long 123 35.7′ W), by the TARA DAWN, a commercial trawler fishing at a depth of 540 fathoms (988m). The trawl catch in which the velvet whalefish was taken included: Dover sole, *Microstomus pacificus;* sablefish, *Anoplopoma fimbria;* and shortspine thornyhead, *Sebastolobus alascanus.* Measurements (after preservation) and counts are as follow: total length 325 mm, standard l. 275 mm, head l. 108.3 mm, orbit w. 8.0 mm, maxilla l. 74.1mm, weight 371.0 g., D rays 22, A rays 17, gill rakers 5+16=21, principal caudal rays 10+9(?), vertebrae (incl. urostyle) 18+25=43. The specimen is deposited at the California Academy of Sciences, CAS 59660.

Barbourisia rufa is an extremely rare bathypelagic cetomimoid (order Beryciformes, family Barbourisiidae) (Nelson 1984) which has a cosmopolitan distribution, except as higher latitudes. As commercial fisheries develop in greater depths off our coast, new and unusual species will continue to be added to the California marine fauna.

I would like to thank Tom Estes, skipper of the TARA DAWN, for saving this unusual specimen in the interest of science. Konstintin Karpov and Chris Vreeland, California Department of Fish and Game, Fort Bragg, provided the fish for study. M. Eric Anderson, California Academy of Sciences, and Richard H. Rosenblatt, Scripps Institution of Oceanography, commented on the manuscript. This research was supported in part by Federal Aid in Fish Restoration Act funds to California Dingell-Johnson F-25-R, Central California Marine Sportfish Survey.

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—Robert N. Lea, Marine Resources Division, California Department of Fish and Game, 2201 Garden Road, Monterey, California 93940. *Accepted for publication February 1987.*

BOOK REVIEWS

THE MIGRATION OF HAWKS

By Donald S. Heintzelman. Indiana University Press, Bloomington, Indiana. 1986. xiv + 369 p.; cloth, $35.00

The author, generally regarded as the salient student of raptor migration in the United States, developed this volume as an expansion of his original opus, *Autumn Hawk Flights,* published more than a decade ago. Subsequently, the growing interest in this subject has produced a significant increase in studies of migration and hawk watching in general by both the public and the scientific community, and a concurrent great increase in publication about raptor migration. The author succinctly states the purpose of the present volume is "to organize and summarize the most important New World hawk migration literature and evaluate the current (through 1984) status of our knowledge of these migrations." He has certainly most effectively achieved that stated goal, by expanding the coverage seasonally beyond the emphasis of autumn data in the earlier work, and the geographic coverage for the entire North American continent rather than merely the U.S. eastern states.

The Migration of Hawks contains four parts, devoted respectively to History and Field Study Methods, The Hawk Lookouts, Hawk Migrations and Weather Conditions, and Migration Routes, Geography and Hawk Counts. The History section begins with a review of previous efforts to systematic study raptor migration, including who made such efforts and their motives, methodology (much of this in earlier days simply over a shotgun barrel for sport), and the accent of investigations, including migration seasonal span, bird flight speed, distance covered, nomadism and nocturnal activity. Part two, discussing hawk lookouts, systematically divides the coverage in geographical zones (Eastern Canada, Great Lakes, etc.) and even includes data for Central America and the West Indies. Perhaps the most instructive portion of this section is the obvious lack of significant coverage in some parts of the continent and the clearly identified need to fill that void. Part three includes the relationship of hawk migration to general weather systems, local weather variables, deflective updrafts and thermals, altitudes, daily rhythms and noon lulls in flight patterns. This latter part is particularly valuable for the student that anticipates initiating studies in a new area and must budget time and effort for the most productive study results, especially if such resources are restricted; in short, when to concentrate efforts on the most likely action.

Part four considering routes and geography discusses differential flight according to raptor age classes, and the routes identified. There is a final thought-provoking discussion of just how accurate hawk counts on migration routes serve as indices of raptor population trends.

Seventeen clear and well-constructed figures and five maps summarize at a glance many of the important discussions within the text, and the migration student cannnot but be overjoyed and astonished by the breadth of the Literature Cited section with its 61 and a half pages of entries which well attests to both the author's knowledge of the subject and the thoroughness of his efforts to document his conclusions. The book is well written and apparently devoid of printing errors. From my own relatively parochial interest in raptors along the Pacific coast, I was a much impressed with what we apparently do not yet know as opposed to what we do, in spite of the recent efforts of Binford and other raptor migration pioneers in our area.

The book is a remarkable and valuable effort and should be within reach of every serious student of raptors and migration, who can then identify and contribute to filling in the voids in our knowledge identified by the author.

—Bruce G. Elliott

COLORADO'S LITTLE FISH, A GUIDE TO THE MINNOWS AND OTHER LESSER KNOWN FISHES IN THE STATE OF COLORADO

By John Woodling. 1985. Colorado Division of Wildlife, Denver. 77 p., $3.00 (softcover), and

FISH CULTURE AND STOCKING IN COLORADO, 1872–1978

By William J. Wiltzius. 1985. Colorado Division of Wildlife, Denver, Division Report No. 12. 102 p., $5.00 (softcover)

Not long ago I was flying back to California following a visit to the east coast, where I had presented seminars at Yale University relating environmental ethics to the preservation of desert fishes. Shortly after leaving Denver I happened to look down upon Flaming Gorge Reservoir and the Green River as it flows through Dinosaur National Monument. During the Yale lectures I had referred to the tragedy of September 1962, when the total fish fauna and much of the remaining aquatic life were eradicated in more than 500 miles of the Green River system in Wyoming, Utah, and Colorado by a consortium of state and federal fish and wildlife agencies. The purpose of this project was to satisfy political and economic pressures to enhance a fishery for rainbow trout, an introduced species. This event created a major rift between government fishery managers and the nation's ichthyologists that persists to this day. It ultimately involved the personal attention of Interior Secretary Stewart L. Udall.

Viewed in this context, "Colorado's Little Fish" assumes a position of extraordinary importance. In the era of the Green River incident, a book devoted to the biology of nongame fishes and produced by a state fish and game agency would have been most unlikely. The philosophical implications of this new volume, therefore, parallel its scientific value.

John Woodling has done a fine job in compiling a vast amount of excellent information concerning Colorado's nongame fishes. A realist, he includes introduced and exotic species along with the natives. Like it or not, they are there and must be considered a part of the ecosystem.

Following a brief introduction, Woodling describes previous studies of Colorado's fish fauna, its river basins, and its habitat types, leading into a sobering discussion of Man's impacts. He ends the preliminary sections with a description of the current status of Colorado's fishes, in which he wisely cautions the reader to exercise great care when using and distributing bait fish. If only we could turn the clock back 150 years!

A layman's guide to fish structure precedes a key to Colorado's fish families, and this leads into the main section of the book. Ten families are represented by a total of 50 species, and, where appropriate, keys to the species level are included. Species descriptions are followed by information on range, habitat, and life history, including distribution by county. Excellent photographs, most of them in color, are included for all but two species. Color reproduction is well above average. It is well written and edited, and typographical and grammatical errors are minimal.

The book is directed to a lay readership, extending through bait dealers, the general public, and high school and first year college biology students, and it should fulfill its purpose admirably. Keys are easy to use, and a very good glossary should allow any competent lay person to use them successfully. Despite its general orientation, the book contains enough solid information to warrant a place in the reference library of the professional ichthyologist or fishery scientist.

Other states have produced checklists and keys to their fish fauna, but "Colorado's Little Fish" is the best yet. It appears that our development of values and ethics relative to the nation's fish fauna may finally be progressing at a rate comparable to the evolutionary rate of our fellow creatures. It has been slow in coming. Aldo Leopold observed that the first principle of intelligent tinkering is to keep all the parts, and perhaps we are finally on the right track. "Colorado's Little Fish" will do much to enhance the public understanding that inevitably must accompany strong and sustained programs designed to preserve nongame fish and wildlife. We have made much progress in the quarter century since the Green River tragedy. With Colorado's lead, I look forward to the day when my bookshelf may contain 50 such volumes.

"Fish Culture and Stocking in Colorado, 1872–1978" constitutes the second feather in Colorado's cap, although from a different perspective. William Wiltzius provides a complete history of fish culture and stocking in Colorado, and, from my experience in California, it seems that what has happened in Colorado is typical of the western states in general. Until rather recently, it seemed to be the consensus among fishery managers that "if it had fins and liked the water" it should be planted somewhere. Historically, little concern has been expressed over long-term ecological implications, particularly in relation to the effect of introduced or exotic fishes on native species. More than a book per se, this volume represents an encyclopedic compendium of facts, even including life history information that may be of value in reestablishing threatened and endangered fishes.

It is of interest that this book had its origins in litigation involving the U.S. Fish and Wildlife Service and certain Colorado water conservation districts that required documentation on stocking of various nonnative fishes into the Colorado River system. The author then expanded the initial research into the present document. In addition to private, state, and federal fish culture efforts, he also includes information on early laws, commercial fishing operations, and the formation and involvement of sportsmen's groups.

The book is abundantly illustrated with black and white photographs depicting the early evolution of fish culture methods within Colorado, following which are valuable tables summarizing the distribution of fishes from Colorado's hatcheries between 1872 and 1978, and also documenting the earliest known introductions of nonnative species. This latter list even identifies the parties responsible for such introductions, should frustrated fishery scientists wish to prepare the appropriate voodoo dolls!

I found Wiltzius' Appendix B of great interest. This section describes some of Colorado's early fish culturists and their facilities, supplementing the author's own account with pertinent articles and photographs from early documents, newspapers, libraries, and other sources of historical information. His in-depth treatment of certain of the more influential individuals of the era is of special value by providing insight into early management decisions that have assumed great importance in later years.

Actually, there is so much diverse information in this book that it defies detailed review. Anyone with an interest in ichthyology and/or fisheries management will be intrigued by it, and only one who has spent vast amounts of time in historical research can even begin to appreciate the monumental effort that the book represents. Hats off to John Woodling, William Wiltzius, and the Colorado Division of Wildlife! They have set an example that should be emulated by every state.

—*Edwin P. Pister*

MISCELLANEA

Call For Papers

"Endangered and Sensitive Species of the San Joaquin Valley, California: A Conference on Their Biology, Management, and Conservation" will be hosted by California State College, Bakersfield on December 10 and 11, 1987. The California Energy Commission and California State University, Stanislaus are co-sponsors and organizers of the Conference. California State University, Fresno, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, California Department of Fish and Game, San Joaquin Valley Chapter of The Wildlife Society, The Kings River Conservation District, and Southern California Edison are also key organizers of the conference.

Papers and poster sessions on endangered and sensitive wildlife and plant species and unique communities of the San Joaquin Valley are requested. Topics include: taxonomy, ecosystems, life history, management, impact assessment, mitigation, laws and agencies, habitat restoration, preserve design, and development impact and trends. Presentations are 15 minutes. Accepted papers will be published in the Conference Proceedings.

Abstracts (5 copies) should be sent to Daniel P. Williams, Department of Biological Sciences, California State University, Stanislaus, Turlock, Calif. 95380, by July 1, 1987.

For additional information, contact Linda K. Spiegel, California Energy Commission, 1516 9th Street, MS-40, Sacramento, Calif. 95814.

Endangered Species Bulletin

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INSTRUCTIONS TO AUTHORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish and wildlife. Original manuscripts submitted for consideration should deal with the California flora and fauna or provide information of direct interest and benefit to California researchers. Authors may submit an original plus two copies, each, of manuscript, tables, and figures at any time.

MANUSCRIPTS: Authors should refer to the *CBE Style Manual* (Fifth Edition) and a recent issue of *California Fish and Game* for general guidance in preparing their manuscripts. Some major points are given below.

1. *Typing*—All material submitted, including headings, footnotes, and literature cited must be typewritten doublespaced, on white paper. Papers shorter than 10 typewritten pages, including tables, should follow the format for notes.

2. *Citations*—All citations should follow the name-and-year system. The "library style" will be followed in listing literature cited.

3. *Abstracts*—Every article must be introduced by a concise abstract. Indent the abstract at each margin to identify it.

4. *Abbreviations and numerals*—Use approved abbreviations as listed in the *CBE Style Manual.* In all other cases spell out the entire word.

TABLES: Each table should be typewritten with the heading margin left justified. Tables should be numbered consecutively beginning with "1" and placed together in the manuscript following the Literature Cited section. Do not double space tables. See a recent issue of *California Fish and Game* for format.

FIGURES: Consider proportions of figures in relation to the page size of *California Fish and Game*. The usable printed page is 117 by 191 mm. This must be considered in planning a full page figure, for the figure with its caption cannot exceed these limits. Photographs should be submitted on glossy paper with strong contrasts. All figures should be identified with the author's name in the upper left corner and the figure numbers in the upper right corner. Markings on figures should be made with a blue china marking pencil. Figure captions must be typed on a separate sheet headed by the title of the paper and the author's name.

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