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CONTENTS

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FRESHWATER EELS (FAMILY ANGUILLIDAE) IN CALIFORNIA: CURRENT CONDITIONS AND FUTURE SCENARIOS [1]

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Exotic freshwater eels of the genus *Anguilla* (family Anguillidae) have been found in California in increasing numbers, probably the result of their accidental and/or intentional release. Increasing consumption of freshwater eels has engendered plans for largescale introduction of living eels, requiring an investigation of hazards associated with their introduction as adults or juveniles destined for growout facilities. A key to the identification of selected *Anguilla* is provided. New records of 17 specimens of *A. anguilla, A. australis* and *A. rostrata* (and several reliable observations) from southern and northern California are discussed. The life history of several *Anguilla* species is summarized and discussed, suggesting that their escapement, possible establishment, predation upon and competition with the native fauna, and disease introduction are likely events if importation of live eels continues.

INTRODUCTION

Freshwater eels of the genus *Anguilla* (family Anguillidae) are not native to the western United States. Their introduction has been attempted on numerous occasions but, due to their curious catadromous reproductive behavior, none has been successful. In recent years, specimens of adult *Anguilla* have been discovered in California waters, apparently the result of accidental and/or intentional release. The desirability of *Anguilla* as a food fish has seen the introduction during the last decade of large numbers of living juvenile and adult specimens. The California Department of Fish and Game (CDFG), cognizant of the potential ecological consequences of such large scale importations, requested the advice of the California Academy of Sciences. This paper is a summary of that report along with additional records of California specimens of freshwater eels.

Live anguillid eels have become popular in restaurants and markets, particularly among the Asian-American communities and young urban professionals. The demand far outstrips the supply. Eel farms have been established with limited success in many southeastern states in order to supplement wild stocks of *A. rostrata* (Fahay 1978). Attempts have occurred in Colorado and Utah to raise eels in geothermal waters (Rickards 1980). Recent proposals to the California Department of Fish and Game have involved the importation of adult anguillids and/or young eels ("elvers") which would be raised in growout facilities. The State of Hawaii, in 1973 and 1983, rejected major programs involving eel culture and/or adult eel importation because it was felt that the biological risks outweighed the economic benefits. On 4 December 1987, the

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California Fish and Game Commission decided for similar reasons to add all species of *Anguilla* to the list of species prohibited from live entry into California.

The primary concerns which should be satisfied before allowing the introduction of anguillids, either as young or as adults, are as follows: i) escapement, ii) establishment of reproducing populations, iii) predation upon and competition with native species, and iv) introduction of exotic diseases and parasites. The following sections address them.

TAXONOMY AND LIFE HISTORY SUMMARY

Sixteen species of anguillid eels, all within the genus *Anguilla,* are currently recognized (Ege 1939, Xinyu and Zenyi 1988, D. Smith in press). The most likely candidates for introduction are: *A. rostrata,* the American eel; *A. anguilla,* the European eel; *A. japonica,* the Japanese eel; *A. dieffenbachii,* the longfinned eel; and *A. australis,* the shortfinned eel. Although behaviors and physiological tolerances vary among and between species (cf. Skrzynski 1974, Moriarty 1978, D. Smith in press), freshwater eels are very similar in appearance and difficult to identify to the specific level. Identification of most species requires x-ray capabilities (necessary for counting vertebrae) and familiarity with subtle differences in dentition and body proportions. It may reasonably be presumed that laboratory personnel lacking x-ray capabilities will have difficulty with the identification of specimens to the specific level. A key to the identification of the above-listed species of *Anguilla* is provided as Appendix 1 to this paper.

Anguillids are catadromous and, although the migration pattern of adult Atlantic *Anguilla* to the spawning grounds in the Sargasso Sea is becoming better understood, the spawning locations of the 14 Indo-Pacific species are still unknown. The current distribution of anguillids is probably related to the accessibility of spawning areas. They are absent from Hawaii, South America, and the entire eastern Pacific. Most adult anguillids are warm-temperate to subtropical in temperature tolerance, and based on the breeding behavior of the Atlantic species, it seems that they require an oceanic current system that will allow the leptocephali larvae to return to the coast. Known breeding areas are characterized by warm water at relatively great depths. The Sargasso Sea typifies that condition, having temperatures above 15° C at −400 m and, being in the center of the North Atlantic gyre, allowing leptocephali to return via the Gulf Stream. It is extremely unlikely that a similar breeding opportunity could exist off California due to the oceanic conditions.

Anguillids are abundant in their native waters. Estimates of American eel *(A. rostrata)* populations indicate that they may comprise more than half of the fish biomass by weight in a given body of water (Smith and Saunders 1955; M. Smith 1966; Ogden 1970). They are among the hardiest of fishes. Their tolerance of a broad temperature range as well as the breadth of benthic habitats that they can occupy is well established (Fahay 1978). European eels can survive near freezing temperature. American eels were once found to survive the cooling system process of a nuclear plant; after three days, two living eels were found in the aftercanal, having been exposed to elevated temperatures of 28° C for 50–100 minutes (Marcy 1973).

It is most likely that a variety of eel predators would exist within the California ichthyofauna. Numerous potential carnivores could consume anguillid elvers.

Juvenile and adult eels are preyed upon by older eels (Sinha and Jones 1967b), larger piscivores, and birds such as bald eagles and herring gulls (Seymour 1974). Eels are not desirable sportfishes but are actively sought by Asian and European fishermen because of their epicurian qualities.

The ability of *Anguilla* to resist confinement is remarkable. The mobility of adults and elvers rivals, if not exceeds, that of all other exotics that have secondarily become the target of eradication programs. Norman (1963) described their athletic prowess thusly:

> ". . . Few obstacles seem too great to be overcome by the elvers in their ascent, and they will wriggle over weirs, etc., and travel overland if the ground be wet in order to reach a suitable resting place. Here they will feed and grow for some years until the time arrives for them to set off on their own breeding migration."

It is well known that eels can travel overland during rainy periods; thus it is unlikely that any pond impoundment system will satisfactorily contain them. The numerous *Anguilla* spp. that have recently been captured in California were more likely the result of released individuals, because few holding facilities exist at present.

The feeding habits of *Anguilla* spp. are fairly well documented (Sinha and Jones 1967b, Skrzynski 1974, Moriarty 1978, and see Beumer 1979 for a comprehensive review). Prey composition changes with eel size; smaller eels feed primarily upon benthic insects and larger eels feed upon fishes and crayfish (Ogden 1970). Fahay (1978) summarized the omnivory of the American eel:

> "A list of species serving as food for the eel has to include virtually the whole aquatic fauna (freshwater as well as marine) occurring in the eel's area. The food list might easily be augmented with animals living out of water, e.g., worms, while fresh meat is taken as well. With eels in captivity, unlike most other creatures, there is no difficulty in inducing them to feed, and they will thrive on practically any diet."

Special consideration should be given to their rapacious nature, even to the degree that they could be a serious problem to certain juvenile waterfowl. Roughly (1951) described Australian *Anguilla* as follows:

> "In view of the fact that there is so little demand for eels in Australia they can be viewed only as being in the nature of pests, for they destroy large quantities of fish that are appreciated by the public and, when occurring in streams containing trout, they prey on these valuable sporting fish extensively. In North Gippsland farmers who endeavour to raise ducks are pestered by eels, which bite off the legs of the ducklings when swimming or drag them to the bottom to consume them."

Roughly (1951) and others (cf. Fahay 1978, p. 34) are concerned with trout in the eel's diet; however others have suggested that trout are infrequently consumed (Burnet 1952, 1968, 1969; Ogden 1970; Sinha and Jones 1967b; Skrzynski 1974). Nonetheless, recognizing the omnivorous nature of anguillids, and recognizing that Pacific Coast salmonids and other native species have not coevolved with anguillids, it is reasonable to presume that trout, young salmon, and their own prey will be consumed by eels. It is also clear that anguillids are in competition with some salmonids for the same food resources.

It is presumed but not demonstrated that anguillids do not survive beyond spawning. Otoliths, the structure used for most aging studies (Frost 1945, Sinha and Jones 1967a, Ogden 1970), indicate that *Anguilla anguilla* may reach 30 years or, purportedly, even 50 years (Moriarty 1978). It has been suggested that some landlocked eels which are unable to return to sea live even longer, a situation that might well occur in California. Growth is relatively linear with age, with older individuals of *A. rostrata* reaching ca. 1 m in length.

The probability of introduction of new diseases, pathogens, and parasites with *Anguilla* introductions is high. Numerous viruses, bacteria, nematodes, trematodes, sporozoans, and other diseases and parasitic organisms have been isolated from cultured and wild anguillids (Fahay 1978, Inman and Bland 1981, Rickards 1978). This will not only create a difficulty for eels in culture, but may also be transmissible to native fishes. Because the entire life cycle of anguillids cannot be replicated in captivity, all culture will therefore depend on supplies taken from the wild. The intensive, large scale husbandry involved with a grow-out facility would necessitate large quantities of elvers and repeated importations. It is neither practical nor possible to expect that any inspection program could screen for diseased or parasitized individuals. Many of the pathogens and diseases can be spread by effluent discharge itself. That, combined with the well-demonstrated ability of eels to escape confinement, should establish that an unpredictable level of undesirable elements will be introduced to California aquatic ecosystems.

CURRENT CALIFORNIA STATUS

Historic attempts in 1874, 1879, and 1882 to introduce *Anguilla rostrata* in California were unsuccessful (Shelby 1917; Evermann and Clark 1931). Skinner (1971) reported on adult *Anguilla* captured near Stockton (San Joaquin County) in 1964, and near Byron (Contra Costa County) in 1969. The Byron specimen (CAS 27136, 925 mm) is intact and was identified by W. I. Follett as *A. anguilla*. The Stockton specimen (SIO 64-219) is only a skin, and appears to be either *A. anguilla* or *A. rostrata*. Skinner proposed that they had entered the Delta via foreign ship ballast. This is a most unlikely explanation, particularly if the eels are Atlantic anguillids. More plausible avenues of introduction might be considered.

The increasing popularity of live anguillids in California restaurants and markets has coincided with a large increase in the number of incidental captures by fishermen and eel removal from fish screens. Appendix 2 of this paper presents data for recent specimens of *Anguilla* from California.

Deposited in the fish collection of the California Academy of Sciences are 14 specimens (from nine separate collections) of *Anguilla* taken between 1977 and 1984. The collection locales include Stow Lake (San Francisco County), Byron, San Pablo Bay, and Tracy (San Joaquin County). David P. Drake, a fisheries biologist with CDFG, reports (in litt. 3 Mar. 1987) that *Anguilla* were found in the lower Los Angeles River in 1978–79, in Puddingstone Lake (Los Angeles County) in 1983 (and three subsequent specimens, same locale), and in Legg Lake (Los Angeles County) in 1985. Of those specimens, two from Puddingstone and the Legg Lake specimen are positively identified as *A. australis*. Camm Swift, an ichthyologist with the Los Angeles County Museum of Natural History, related (in litt. 18 Feb. 1988) the following reliable records for which specimens

are unavailable: on "13 May 1983 Louise Fiorillo, a CFG Warden told me that since the previous October, that she had seen about two dozen *Anguilla* taken from Legg Lake"; and that Eric Knaggs of CDFG "remembered two additional *Anguilla* from the Willow Street bridge on (the) L.A. River, Long Beach in August, 1979." Similar captures of *Anguilla,* not identified to species, have occurred in Lake Mead, Nevada (Deacon and Williams 1984). It is therefore apparent that anguillids are either escaping from captivity and/or being released into the wild.

No elvers are known to have been captured in California waters, further suggesting that reproducing populations do not exist in the State. The presence of adult *Anguilla* in California appears to be the result of a cautious tolerance by the CDFG of importation of live eels from sources in New Zealand, Florida, and possibly Japan. The history as explained by Almo J. Cordone, Fisheries Management Supervisor of the Department, is as follows (in litt., Cordone to J. C. Kelley, 28 May 1987):

> "We became aware of the presence of live eels in metropolitan retail outlets in 1985; a practice that apparently started several years earlier. At the request of New Zealand authorities, we allowed the trade in eels to continue as long as all fish were held in closed systems and killed at the time of sale. We considered this an interim solution until we could ascertain the biology of the different species of eels and the threat of their establishment in California waters."

Requests before the CDFG for substantially increased importation and the possibility of an aquaculture pond growout system necessitated a more restrictive policy.

CONCLUSIONS

In recognizing the hardiness, survivability, and broad range of environmental tolerances represented among the 16 species of *Anguilla,* and presuming that as many as five species are likely candidates for importation, it is appropriate to presume that if released into California waterways, anguillids would survive and be competitive with and predatory upon the native ichthyofauna and introduced gamefishes. This has already been demonstrated by the small scale accidental and/or intentional releases now being observed. Their ability to escape confinement is well known, emphasizing that total confinement is impossible for anguillids. The variety of parasites and disease organisms that will accompany anguillid introduction is considerable and caution should be employed lest any major new pathogen be introduced to the California native ichthyofauna and/or aquaculture and hatchery programs. It is most unlikely that anguillids could leave California freshwaters, reproduce in the sea, and return. That presumption is based primarily on the American species of *Anguilla;* it is possible, but unlikely, that an Indo-Pacific species might successfully adapt to California oceanographic conditions.

In summary, given that a large scale anguillid importation and aquaculture grow-out program was established in California, it is reasonable to presume that many adults would find their way into rivers, ponds, lakes and reservoirs in California, and compete with and prey upon native fishes. Anguillids would probably not reproduce but could live 30 or more years after escapement. It

seems appropriate to prohibit any large scale importation program until the risks associated with pathogens and disease and probable competition with and predation upon native fishes are further studied.

ACKNOWLEDGMENTS

Many individuals have provided information and advice and assistance with the specimens used in this study. In particular, I wish to thank: John Ford (U. S. Fish and Wildlife Service, Hawaii); Almo J. Cordone, Betsy Bolster, and David Drake (CDFG); Martin Brittan (California State University, Sacramento); David G. Smith (Harvard University); W. I. Follett, Lillian J. Dempster, William N. Eschmeyer, David Catania, and Eric Anderson (California Academy of Sciences, CAS); Robert J. Lavenberg and Camm Swift (Los Angeles County Museum of Natural History, LACM); and Richard H. Rosenblatt (Scripps Institution of Oceanography, SIO). This paper benefitted from Leighton Taylor's (CAS) critical reading and suggestions from Paul Reilly (CDFG) and Jack Williams (US Fish and Wildlife Service).

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APPENDIX 1.
KEY TO THE IDENTIFICATION OF SELECTED SPECIES OF *ANGUILLA*
(modified from Ege 1939)

1a. Dorsal fin begins approximately above the anal fin origin; eye directly above angle of jaw . . . Shortfinned Eel, *A. australis* Richardson (from Australia, Auckland Islands and New Zealand)

1b. Dorsal fin begins well in advance (more than ½ head length) of anal fin origin; eye in advance of angle of jaw . . . 2

2a. Upper jaw about 3 X (32–36%) in head length . . . Longfinned Eel, *A. dieffenbachii* Gray (from Australia, Auckland Islands and New Zealand)

2b. Upper jaw shorter, about 4 X (25–27%) in length of head . . . 3

3a. Maxillary bands of teeth with a longitudinal groove; average maximum length of preanal distance without head 27% of total length . . . Japanese Eel, *A. japonica* Temminck and Schlegel (from China and Japan)

3b. Maxillary bands of teeth without a longitudinal groove; average maximum length of preanal distance without head 30–30.3% of total length . . . 4

4a. Total vertebrae 103–111; average maximum value of distance between verticals through anal and dorsal fin origins 9.1% of total length . . . American Eel, *A. rostrata* (Lesueur) (from North America, Greenland and the West Indies)

4b. Total vertebrae 110–119; average maximum value of distance between verticals through anal and dorsal fin origins 11.2% of total length . . . European Eel, *A. anguilla* (Linnaeus) (from Europe, Iceland and North Africa)

APPENDIX 2.
CALIFORNIA SPECIMENS EXAMINED

Anguilla anguilla: CAS 39012, 740 mm, San Pablo Bay, at Antioch Bridge, "1977 or before", from J. Skinner; identified on the basis of its having 11 c vertebrae.

Anguilla australis: LACM 44140, 704 mm, Los Angeles County, Legg Lake, caught by fisherman, 18 Dec. 1985; otoliths examined by R. J. Lavenberg, indicating that the fish was 7–8 years old; identified on basis of fin position. LACM 43527-1, 682 mm, Los Angeles County, Puddingstone Reservoir, from C. Rodden, 29 July 1983; identified on basis of fin position and 112 vertebrae. LACM unnumbered, 497 mm, Puddingstone Reservoir, from J. St. Amant, 29 June 1983; identified on basis of fin position and 111 vertebrae.

Anguilla rostrata: CAS 41042, 165 mm, San Francisco, Golden Gate Park, Stow Lake, from G. Mallick, 15 Jan. 1978. CAS 41043, 150 mm, as preceding specimen, 22 Jan. 1978. CAS 41044, 3 (140–207 mm), as preceding specimen, 16 Jan. 1978. CAS 41045, 3 (125–180 mm), San Francisco, Golden Gate Park, Water Reclamation Plant, 9 Jan. 1978. CAS 62246, 2 (165–177 mm), Golden Gate Park, Stow Lake, 8 Feb. 1978; identified on the basis of having 108 and 109 vertebrae. CAS 44056, 330 mm, Golden Gate Park, from a faucet (probably of the same year class as the preceding Golden Gate Park specimens), 28 Mar. 1979. CAS 53928, 515 mm, Tracy, screen at fish facility, from B. Bolster, 13 Oct. 1983. CAS 62206, 720 mm, Contra Costa County, Delta Protective Facility near Byron, from B. Bolster, 27 Apr. 1984.

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MIGRATION PATTERNS OF MULE DEER IN THE CENTRAL SIERRA NEVADA [1]

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Migration routes, holding areas, and winter ranges were identified for California and Rocky Mountain mule deer, *Odocoileus hemionus californicus* and, *O. h. hemionus,* respectively, inhabiting summer range in McCormick Creek Basin in the central Sierra Nevada, California. Radio-collared does migrated 27–51 km to winter ranges administered as 4 different herd units. Does migrating to the same winter range area also had high overlap in summer home ranges. In 1983, many does dropped their fawns on spring holding areas because the heavy snowpack precluded occupancy of summer ranges until July. Holding areas were used for a longer period of time during spring than during fall migrations. In the fall, deer generally traveled directly to the winter range upon leaving the summer range, but delayed upslope of specific winter home ranges during periods of mild weather. Habitat improvements to enhance forage and cover on spring and fall transitional ranges would be especially beneficial to deer following severe winters when deep snow prevents normal occupancy of summer range. Such habitat improvement projects would also reduce deer impacts on important winter range resources during the fall by offering desirable seral habitat. Large areas of contiguous habitat, in this case a state game refuge, provide winter range to deer with little disturbance from humans. Rocky Mountain mule deer wintering east of the Sierra Crest in Great Basin communities used valley bottoms and south facing mountain slopes as holding areas and winter ranges.

INTRODUCTION

Determining seasonal ranges used by deer is an important component of deer herd management. Knowledge gained from biotelemetry studies can aid resource managers by identifying areas which have the greatest potential return in deer herd productivity through habitat maintenance and improvement projects. Winter ranges, migration routes, holding areas and summer ranges can all be identified by monitoring radio-collared deer (Schneegas and Franklin 1972, Bertram and Rempel 1977, Loft, Menke and Burton 1984).

From 1982 to 1985, California mule deer, *Odocoileus hemionus californicus,* and Rocky Mountain mule deer, *O. h. hemionus,* inhabiting summer ranges in the McCormick Creek Basin (hereafter referred to as the Basin) of the Stanislaus National Forest were monitored to determine timing of migrations and routes taken between summer and winter ranges. Rocky Mountain mule deer winter on the east slope of the Sierra Nevada while California mule deer winter on the west slope. The objectives of this study were to identify migration routes, holding areas, and winter ranges of deer summering in the Basin. This

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information would delineate areas for consideration in habitat improvement projects or protection from development.

STUDY AREA

The total area that would be inhabited by deer radio-collared during the study encompasses an area from the foothills on the west slope of the Sierra Nevada near Sonora, California, across the Sierra Crest, and east to near Topaz Lake, Nevada (Fig. 1 and 2). The dominant plant communities (following Munz and Keck 1965) on West Slope winter ranges between 550-1,400 m elevation are Foothill Woodland, Chaparral, and Yellow Pine Forest.

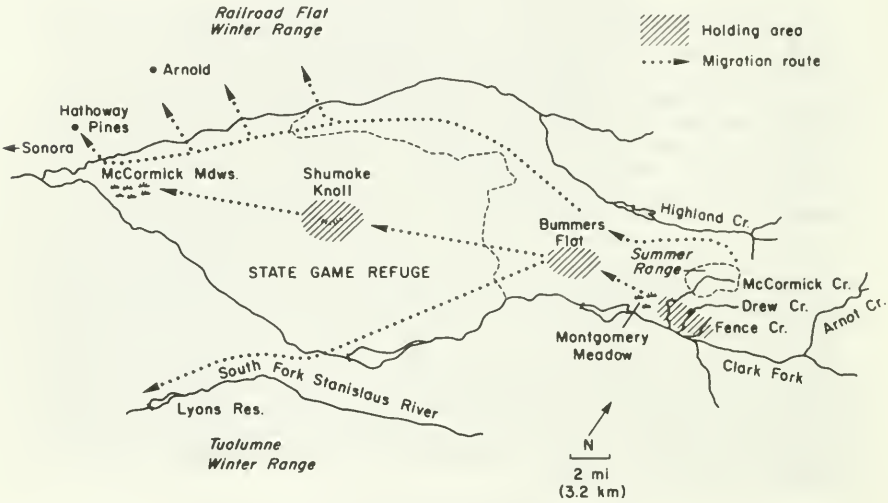

FIGURE 1. Geographical features, migration routes, holding areas, and winter ranges of West Slope California mule deer summering in the McCormick Creek Basin, California.

Yellow Pine Forest also dominates transitional ranges at elevations from 900 to 1,800 m. Meadow and riparian vegetation communities occur along the drainages flowing into the Central Valley and montane shrubfields are common on south aspect slopes. The summer range portion of the study area, at 2,230–2,750 m elevation, is within the Red Fir, *Abies magnifica,* Forest zone. The 490 ha basin is 1.5–2 km in width, with much of the perimeter defined by precipitous volcanic cliffs that are natural barriers to movement. General ecology of deer and vegetation communities in this region have been described (Leopold *et al.* 1951, Browning, Schulenberg and Brunetti 1973, Maddox 1984).

Winter ranges on the East Slope at 1,580–2,010 m typify Great Basin communities. Vegetation is dominated by Pinyon-, *Pinus monophylla,* Juniper, *Juniperis* sp., and Sagebrush-, *Artemisia* sp., Scrub communities. East Slope winter ranges characteristically have low vegetative cover of trees, shrubs, and herbaceous species (Dasmann and Hjersman 1958).

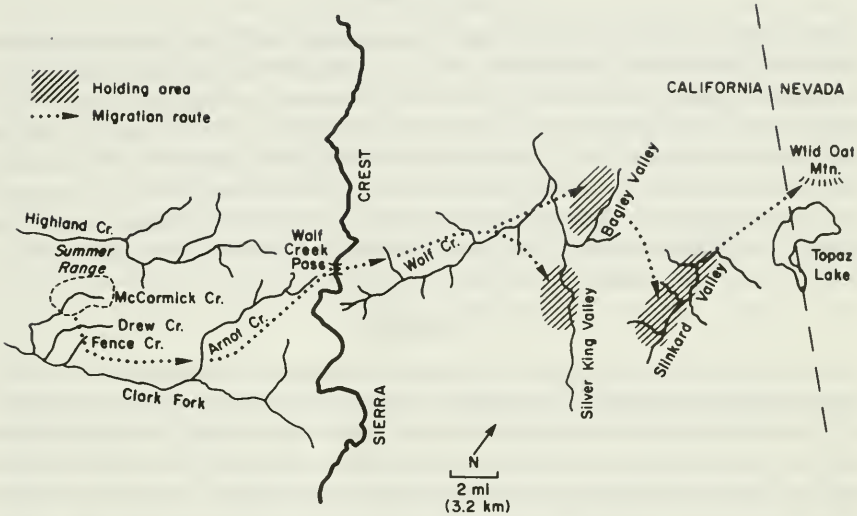

FIGURE 2. Geographical features, migration routes, holding areas, and winter ranges of East Slope Rocky Mountain mule deer summering in the McCormick Creek Basin, California.

METHODS

Deer were trapped and radio-collared on summer range in the Basin to monitor their response to different cattle grazing levels (Loft 1988). Clover traps (Clover 1956) attached to Stewart-modified corral traps (Rempel and Bertram 1975) were built around salt licks. A disturbing number of mortalities (5) occurred within a few days after trapping and were attributed to capture myopathy (stress) induced by selenium deficiency (Chalmers and Barrett 1982, D. Jessup, pers. comm.) and prompted a re-design of the Clover trap. Bowman (unpubl.) designed an external steel pipe frame which suspended the netting about 30 cm away from the pipes. This reduced injury, and apparently stress, to trapped deer as no additional mortalities occurred. Twenty-nine adult does were captured and fitted with radio-collars between 1982–84. Three fawns were also radio-collared in 1984.

Monitoring was conducted primarily from an airplane on all but the summer ranges where permanent antenna sites were established on the ground. Aerial monitoring was similar to methods described by Mech (1983). Some monitoring on the ground using hand-held equipment (Telonics, Inc., Mesa, AZ) was done to help identify spring and fall holding areas. Telemetry precision and accuracy were not determined since the focus of this study was to identify general areas used by deer, and not specific habitat use. Weather permitting, deer were located 1–2 times per week during migration periods, and two times per month during winter. Fall migrations were monitored from 1982–84, and spring migrations from 1983–85.

RESULTS

Summer Range

Radio-collared does exhibited high home range fidelity by returning to the same areas within the Basin each year. The 95% home range area of does on the summer range, determined from minimum convex polygons (Mohr 1947), ranged from 40 to 200 ha ($\bar{x}$ = 97 ha) (Loft 1988). Home ranges of Rocky Mountain mule deer (n = 5) were located in the upper end of the Basin while California mule deer (n = 24) primarily occupied the lower end of the basin. Twin Rocky Mountain mule deer fawns, radio-collared in the lower area of the Basin in July 1984, moved to the upper end of the basin by mid-August, where they spent the remainder of their first summer.

Fall Migration

Migration by deer summering at elevations higher than the Basin was evident by late September as deer moved down and congregated in and near the Basin with the onset of late summer storms. Radio-collared deer left the Basin for the year by the first week of October during heavy storms except in 1983 when mild weather enabled them to remain on the summer range until late October.

The migration route used by most California mule deer was south out of the Basin down a steep ridge to the Fence Creek area, then west along the north side of the Middle Fork of the Stanislaus River (Fig. 1). During fall migration, deer did not delay in a holding area near Fence Creek that was later determined to be heavily used during spring. Some delayed in the area of Bummers Flat for a few days, but most traveled 16–19 km west of the Basin to a 390 km^2 State Game Refuge, 300–2,100 m elevation. Within the refuge, deer delayed in the Shumake Knoll area (1,500–1,900 m elev.) for 1–4 weeks. This holding area has gentle topography, high diversity of forage and cover types, and a low level of human disturbance, all of which undoubtedly contributed to use by deer (J. Maddox, pers. comm.). As the fall season progressed towards winter, deer completed the migration and arrived at their winter ranges.

The distance migrated between summer and winter ranges averaged 40 airline km (range 19–51 km). One California mule deer doe that was the first to leave the summer range each year had an unusual migration pattern that first went about 11 km east of the Basin to Arnot Creek, then west again down the Highland Creek and North Fork of the Stanislaus River drainages to the winter range (Fig. 1).

Rocky Mountain mule deer did not have as great an elevational change in their migration to winter ranges as California mule deer because they wintered at higher elevations. However, they did have to cross more undulating topography between their seasonal ranges. Rocky Mountain mule deer migrated out of the Basin through the Fence Creek area then northeast up the Clark Fork and Arnot Creek drainages and over the Sierra Crest at Wolf Creek Pass (2,700 m elev.) (Fig. 2). Three radio-collared deer delayed in Bagley Valley (1,890 m elev.) for several days before migrating to Slinkard Valley (1,830 m elev.), a holding area that is also used as winter range in mild winters.

Winter

California mule deer wintered at elevations of 610–1,280 m in four areas administered as three different herd units (Longhurst, Leopold, and Dasmann 1952) (Fig. 2). Three does wintered in the southern part of the Stanislaus herd range near Lyons Reservoir in areas also used by the neighboring Tuolumne deer herd. Most of the deer however, wintered within the Stanislaus herd boundary in or near the refuge between the north and middle forks of the Stanislaus River. Twelve does wintered in the McCormick Meadows area, while four others wintered farther west near the town of Hathaway Pines. Five deer crossed to the north side of the river's north fork and wintered in the Railroad Flat deer herd area. Does wintering as a group in the same area were later determined to have the greatest overlap in their summer home ranges in the Basin.

Deer returned to the same winter range areas each year, although specific locations occupied varied with weather conditions. During storm periods, deer wintering at the highest elevations on the winter range moved down in elevation until mild weather conditions prevailed and then returned upslope. Winter ranges were inhabited from early October through mid-May, but the average time period was from early November to late April. Of the three years monitored, deer were on winter ranges the longest time during 1982–83, a severe winter, and the shortest time during 1984–85, a mild winter. Winter 1983–84 was comparatively normal.

Rocky Mountain mule deer wintering in the West Walker herd range traveled east from Slinkard Valley to south aspect slopes on Wild Oat Mountain north of Topaz Lake, Nevada, (1,580–1,710 m elev.) where they remained during the severe winter period (Fig. 2). One doe wintered in Silver King Valley, 1,950 m elevation, despite the presence of snow for most of the winter.

Spring migration
West Slope

Differences among years in the timing of migration corresponded with snow depth levels recorded about 100 km to the north at the Central Sierra Snow Lab (elevation 2,100 m) near Soda Springs, California. Snow remained on the ground until early July in 1983, late May in 1984 and early May 1985.

In 1983, California mule deer remained on their winter ranges at an average elevation of 1,040 m until mid-May, then began a gradual upward movement (Fig. 3) between the middle and north forks of the Stanislaus River drainages. On 25 May, radio-collared deer were at elevations of 1,250 m, and six days later had moved up to 1,770 m. From 31 May to 2 July 1983, deer delayed at elevations of 1,700–2,130 m in the Fence Creek holding area because of the snowpack above in the Basin. It was not until 5 July that all the West Slope does were on the summer range in the Basin.

In 1984, migration began about four weeks earlier than 1983, with some upward movement occurring during the first week of April. Radio-collared deer remained on winter ranges within the refuge at least through 30 April. All were migrating by 14 May and were in the Basin by 18 June.

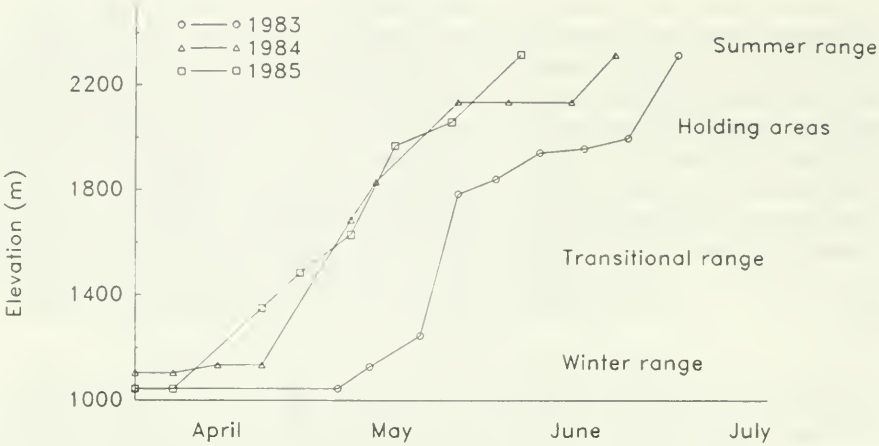

FIGURE 3. Mean elevations inhabited by West Slope Sierra Nevada radio-collared does on specific dates during the spring migration, 1983–1985.

In 1985, the driest of the three years, migration began about two weeks earlier than in 1984, with some deer leaving winter ranges in late April. By 14 May, one doe was in the Basin and the rest were in holding areas. Most deer arrived in the Basin during the following two-week period ending 30 May. Because of the difference in snowpack among years, deer spent less time on holding areas in 1985 compared to either 1983 or 1984 (Fig. 3).

In 1983, we thought that pregnant does might drop their fawns in the holding areas below the basin since the traditional summer range was covered with snow and was uninhabitable until early July. Fawn: doe counts during June and July 1983 (Loft, unpubl. data) indicated fawns were numerous in the holding area below the Basin, but they were not observed in the Basin until late July. During the more normal snow years of 1984 and 1985, fawn: doe counts indicated that few fawns were dropped in the holding areas.

East Slope

The timing of migration by Rocky Mountain mule deer was similar to California mule deer all three years in terms of following the receding snowline. Deer began spring migration from Wild Oat Mountain and moved to Slinkard Valley where they remained for up to 4 weeks until snow levels receded at higher elevations, and then migrated west to Bagley Valley where they stayed for another 1–2 weeks (Fig. 2). Deer then migrated up the Wolf Creek drainage, crossed the Sierra Crest near Wolf Creek Pass, and traveled down into the Clark Fork drainage to the Fence Creek holding area. From there, Rocky Mountain mule deer moved up into the Basin among with California mule deer.

DISCUSSION

Radio-collared does returned to the same summer range area each year, a pattern characteristic of the species (e.g., Gruell and Papez 1963, Bertram and Rempel 1977). Monitoring deer home ranges during summer provided infor-

mation on spacing patterns among individuals (Loft 1988), but additional insight was gained regarding deer behavior when California mule deer does migrated to three winter range areas as separate groups. Does in each winter range group inhabited summer ranges which highly overlapped with other does in the group compared to does that migrated from the other winter range areas. This pattern supports an hypothesis that mule deer does inhabit areas based upon tradition and remain in matriarchal family groups. Others have inferred that this behavior occurs, but it is not well documented (Salwasser, Holl and Ashcraft 1978, Geist 1981, Bertram 1984). The Rocky Mountain mule deer inhabiting the upper portion of the Basin also had overlapping summer home ranges. We did not detect any active segregation between the two subspecies, but unfortunately, little is known of their relationships with each other on sympatric summer ranges.

Congregating in the Basin by deer prior to fall migration is typical of behavior exhibited by other Sierra Nevada deer herds (Hjersman *et al.* 1957, Jordan 1967, Bertram and Rempel 1977) and occurs because deer from higher elevations and more remote summer ranges are first to move down with changes in the weather. The timing of fall migration appears to be influenced by weather conditions because of the differences detected among years and the apparent reluctance to leave the summer range (Bertram and Rempel 1977, Loft, Menke and Burton 1984).

Deer in this study did not use holding areas near the summer range as they have done elsewhere (Bertram and Rempel 1977). Rather, they generally migrated directly to the State Game Refuge, delaying before then only for a few days if mild weather prevailed. Since fall migration usually begins during the first two weeks of the deer hunting season, we may have detected avoidance of hunters by deer, with deer traveling directly to the refuge where disturbance is minimal. We also suggest that habitat quality on fall ranges was suboptimal due to a lack of habitat disturbance, so deer were reluctant to use holding areas and instead migrated directly to their winter ranges. Human disturbance and the availability of desirable forage, particularly oak (*Quercus* sp.) mast and early to mid-seral browse vegetation, are two factors which likely influence fall range use by deer and deserve further investigation. Habitat improvement projects on fall ranges could reduce forage use on limiting winter ranges because deer would likely inhabit transitional ranges for a longer time if more high quality forage were available.

Spring migrations appear to be related to several factors on winter ranges such as increasing temperatures, relative humidity, insect activity, and maturing vegetation (Russell 1932, Leopold *et al.* 1951, McCullough 1964). Accessibility to higher elevation ranges as the snowline recedes and the emergence of forage regrowth in spring are also factors contributing to the timing or rate of migration (Garrott *et al.* 1987). Spring migration occurs as a gradual upward drift that may take two months as deer delay in holding areas where cover and forage are abundant. Holding areas and migration corridors are important for maintaining condition of pregnant does during the third trimester of pregnancy (Holl *et al.* 1979). In most years, does are on their summer home ranges prior to fawning, but following severe winters with a late snowmelt as occurred in 1982–83, fawns were dropped in holding areas below the summer range. Hence, spring holding areas are particularly important habitats following severe winters.

This study revealed that a large geographic winter range area is used by deer inhabiting only a small portion of Sierra Nevada summer range. Winter ranges used by radio-collared does from the Basin are only a sampling of areas important to deer in this region. Seasonal movement patterns in this study illustrate some of the difficulty faced in management of deer in the Sierra Nevada. Effectiveness of programs designed to improve deer productivity in specific herds, such as prescribed burning or special hunts, are difficult to assess because deer do not recognize administrative boundaries. For example, habitat improvement in the Lyon's Reservoir area where some of the study deer wintered may not be reflected in healthier deer summering in McCormick Creek Basin because most of the Basin deer appear to winter elsewhere. Likewise, most of the deer wintering in the Lyon's Reservoir area probably do not have summer ranges in the Basin. Hence, any effort to improve deer herd productivity in one specific area of seasonal range will be reflected in a less dramatic but more widely distributed change in productivity.

Winter ranges used by California mule deer are increasingly being developed as foothill-residential areas. Continued human encroachment onto already limiting winter ranges (Longhurst, Leopold and Dasmann 1952, Maddox 1984) will undoubtedly have a negative impact on the deer. Existing areas of roadless habitat where human disturbance is low should be preserved as they are to maintain suitable large areas of habitat for deer and other wildlife. Deer in this area likely have more favorable conditions than most Sierra Nevada deer herds because much of the winter range is within a game refuge.

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MORTALITY OF TOURNAMENT-CAUGHT LARGEMOUTH AND SMALLMOUTH BASS IN IDAHO LAKES AND RESERVOIRS [1]

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The effects of black bass tournaments on released fish were studied on Idaho lakes and reservoirs from 1981 through 1985. A total of 15 tournaments and 21 tournament days were monitored. Tournaments were evaluated as they were designed by tournament officials and no attempt was made to control variables. We found differences in mortality on tournament-caught bass for both largemouth, *Micropterus salmoides,* and smallmouth bass, *M. dolomieui.* Initial hooking mortality was positively correlated ($r = 0.75$; $P < 0.01$) with increasing water temperature. Length of the tournament day and initial mortality were also positively correlated ($r = 0.67$; $P < 0.01$). Bass held in live cages for 24–36 hours experienced an additional 0.8–9% mortality. Our data suggest that managers should consider reducing the length of bass tournament days and restricting tournaments during times of high water temperature (> 18 C).

INTRODUCTION

Waters in the northwestern United States (U.S.) have traditionally been known for their salmonid fisheries with less interest in warm water species (Wydoski and Bennett 1981). However, in the last decade, fishing for both largemouth, *Micropterus salmoides,* and smallmouth bass, *M. dolomieui,* has become popular in the northwest. Northwestern lakes and reservoirs are at high latitudes and typically provide marginal conditions for black bass because of high elevation (temperatures below optimum). Systems sustaining high quality black bass fisheries probably receive the bulk of tournament fishing pressure, resulting in potentially adverse impacts on bass stocks. In Idaho, most largemouth bass are found in smaller shallow lakes, whereas smallmouth bass are found principally in run-of-the-river reservoirs (river impoundments) such as those on the Snake River (Rohrer 1984).

Tournaments effects on black bass have been studied principally in the southern U.S. Results of these studies indicate that the proportion of tournament-caught fish is small relative to the annual harvest (Holbrook et al. 1972; Holbrook 1975; Schramm et al. 1985). However, the lakes examined were typically large in relation to the restricted habitat available to black bass in

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northwestern lakes and reservoirs. Bass populations have received far less attention by fisheries managers in the northwest because of the extensive angler interest in salmonids (Gordon 1970). As more information about bass populations becomes known, however, more fishermen and managers are expressing concern over the possible detrimental aspects of bass tournaments. Recent concern has been voiced over northern Idaho stocks, which appear to be especially vulnerable to over-exploitation because of slow growth and recruitment (Rieman 1983). Because of the potential negative impact on these "marginal" bass stocks, we measured the mortality from fishing tournaments on both largemouth and smallmouth bass in northern and west central Idaho. This was the first attempt to gather this type of information in the northwestern United States.

METHODS

We monitored catch and mortality from 15 tournaments, representing 21 tournament days from June 1981 to August 1985. In northern Idaho, tournaments were held in backwaters, bays and small lakes associated with the Coeur d'Alene River system (Figure 1). Most fishing occurred in the "lateral" lakes which are relatively eutrophic systems varying in size from 100 to 500 ha, and depths to 10 m (Bowles 1985).

Tournaments were also monitored on Brownlee (6,070 ha) and Hells Canyon (1,037 ha) reservoirs of the middle Snake River system (Figure 1). These run-of-the-river reservoirs were built from 1958 to 1967. Maximum depths of these reservoirs exceed 80 m. Brownlee is the first in a series of three consecutive impoundments and acts as a settling basin for Snake River inflow. As a result, the reservoir receives organic and inorganic wastes from upstream sources and water quality is poor (Ebel and Koski 1968). Hells Canyon is the third reservoir in the series and its water quality is better because of the upstream settling of organics and inorganics.

Contestants fished from 7–12 hours before bass were brought to a weigh-in site and processed by tournament personnel. Fishing duration varied because of different tournament procedures. All participants were required to maintain their catch in aerated live wells. Bass were enumerated and individually weighed in plastic bags, which generally required less than 5 minutes. We counted initial mortalities immediately after weighing. Smallmouth bass were placed in nylon mesh live cages and observed for an additional 30–60 minutes. Largemouth bass were held for an additional 24–36 hours. Cages were 2 m x 2 m and 4 m deep and were covered by a canvas top. Differences in fish handling were dictated by tournament procedures. For example, smallmouth bass tournaments had fewer participants and the weigh-in location enabled project personnel to process data immediately, thus reducing holding time and stress to the fish. Largemouth bass tournaments had considerably more participants and the weigh-in location precluded collecting data until the day after the tournament ended.

Maximum surface water temperatures were recorded at the weigh-in site, whereas maximum air temperatures were obtained from recording stations

(National Oceanic Atmospheric Administration 1983–84). NOAA recording stations were located at Brownlee Dam and St. Maries, Idaho and were less than 20 km from weigh-in sites.

We used correlation and least squares regression analyses to measure the relationship between initial mortality and water temperature, air temperature, fishing day length, and catch.

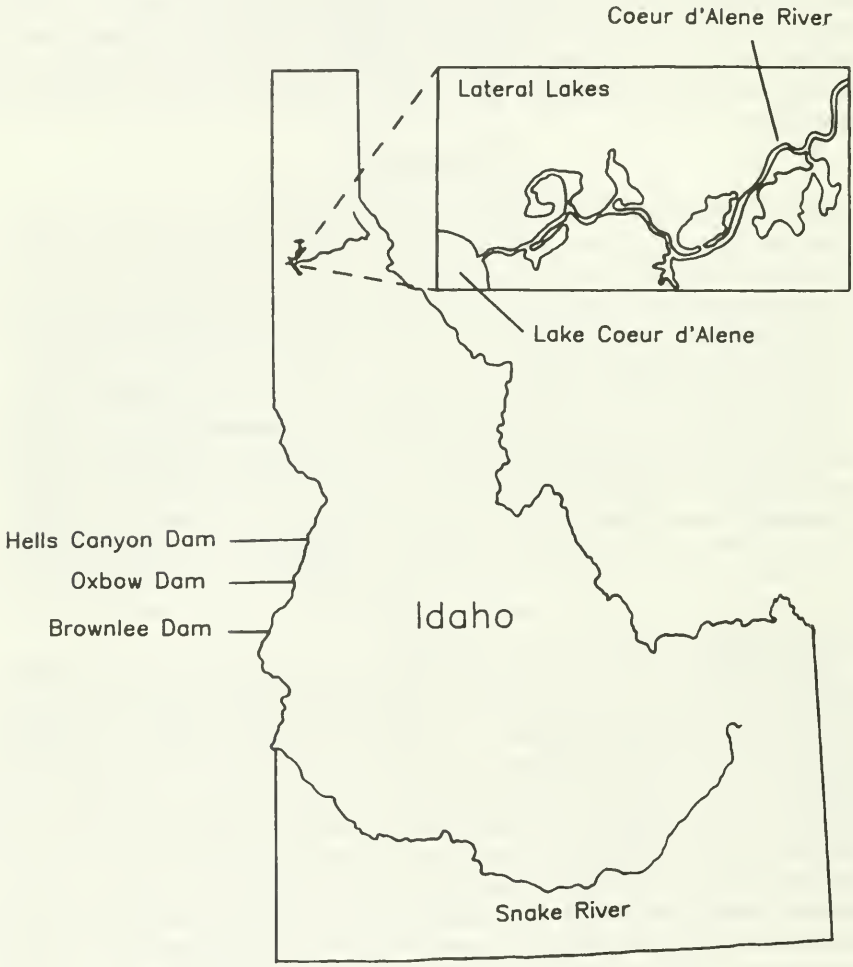

FIGURE 1. Map of Idaho showing locations of the lateral lakes of the Coeur d'Alene River and Hells Canyon and Brownlee Dams.

RESULTS

We found a range of differences in tournament mortality for both largemouth bass and smallmouth bass (Table 1). Initial mortalities were higher for largemouth bass ($\bar{x}$ = 5.7%; SD = 4.8) than smallmouth bass ($\bar{x}$ = 1.2%; SD =

2.7), but the majority of tournaments for smallmouth bass were held earlier in the year when water temperatures along with associated stress were lower.

TABLE 1. Smallmouth (SMB) and Largemouth (LMB) Bass Catches and Mortalities for 15 Tournaments Held Under Different Air and Water Temperature Conditions.

Species	*Date*	*Tournament length (hours)*	*Temperature (°C)*[a] *Water*	*Air*	*No. fish checked*	*Mortality No.*	*(%)*
LMB	6 June 1981	12	18	[b]			
LMB	7 June 1981	8	18	[b]	223[c]	16	7.2
LMB	1 August 1981	12	25	28	119	8	6.7
LMB	2 August 1981	8	25	28	124	4	3.2
LMB	7 August 1982	12	25	36	164	10	6.1
LMB	8 August 1982	8	25	31	143	4	2.8
LMB	15 Sept 1982	12	20	24	[b]	[b]	[b]
LMB	16 Sept 1982	8	20	24	[b]	[b]	[b]
SMB	29 April 1983	8	14	16	92	1	1.1
SMB	16 July 1983	8	21	28	117	10	8.5
LMB	6 August 1983	12	23	34	203	32	15.8
LMB	7 August 1983	8	23	32	130	11	8.5
SMB	8 April 1984	8	7	9	25	0	0
SMB	14 April 1984	8	13	27			
SMB	15 April 1984	8	15	27	84[c]	0	0
SMB	28 April 1984	8	12	13			
SMB	29 April 1984	8	13	16	59[c]	0	0
SMB	5 May 1984	8	9	13			
SMB	6 May 1984	8	9	13	53[c]	1	1.9
SMB	10 August 1985	8	21	17	18	0	0
SMB	11 August 1985	7	22	22	10	0	0
Mean					104.3	6.5	4.1
Standard Deviation					64.5	8.7	4.6

[a] Daily maximum
[b] No sample
[c] Counts determined for 2-day tournaments

The correlation of water temperature and initial mortality ($r = 0.75$; $P < 0.01$) suggests a positive relationship between mortalities and water temperature and higher mortality (Figure 2), whereas the correlation with air temperature was lower ($r = 0.67$, $P < 0.01$; Figure 3). However, when we correlated the natural log of initial mortality of largemouth bass with the natural log of air temperature we found a significant linear relationship (ln mortality $= -15.62 + 5.041$ ln air temp; $r^2 = 0.59$, $P = 0.04$). Our data also indicate a positive correlation between tournament day length and initial mortality ($r = 0.67$, $P < 0.01$). The positive relationship between number of bass caught in the tournament and initial mortality ($r = 0.75$, $P < 0.01$) suggested that higher mortalities occurred with higher catches.

Largemouth bass held in live cages for 24–36 h experienced an additional 0.8–9% mortality. The highest additional mortality after 24–36 h coincided with the tournament with the highest initial mortality.

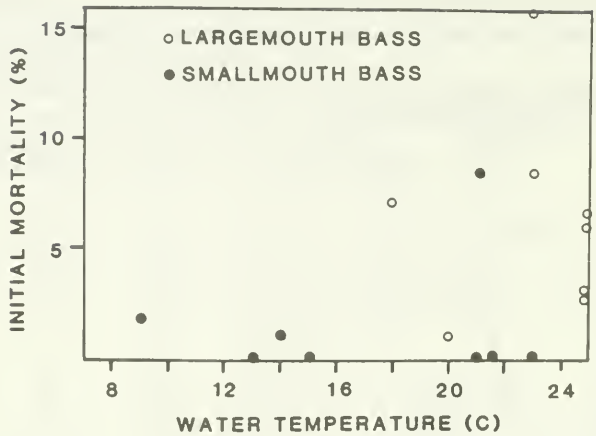

FIGURE 2. Relationship between initial mortality for tournament-caught largemouth and smallmouth bass and water temperature for lakes in Idaho.

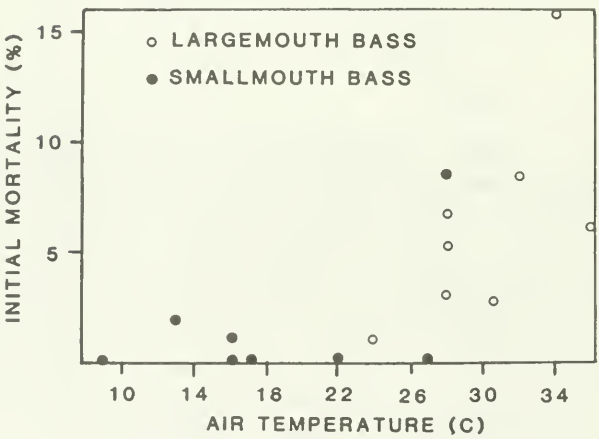

FIGURE 3. Relationship between initial mortality for tournament-caught largemouth and smallmouth bass and air temperature for lakes in Idaho.

DISCUSSION

Initial and latent mortalities observed at black bass tournaments ranged from 0–16% and 0.8–9%, respectively over 21 tournament days monitored during this study. Therefore, a potential total mortality is 25%. These rates are lower than those reported by Holbrook (1975) and Schramm et al. (1985) for the southeastern United States. These estimates are probably lower than what may ultimately occur. Other studies have reported mortality may occur up to 3 weeks following the tournament. However, additional mortality after 36 hours is probably less than 5% (Plumb et al. 1974, Welborn and Barkley 1973). Some mortality of smallmouth bass from Brownlee Reservoir could have resulted from rapid depressurization. Feathers and Knable (1983) reported 40% mortality occurred when largemouth bass were depressurized from simulated depths greater than 18.3 m. Mortality of largemouth bass from depressurization would not have been a factor in the lateral lakes because they are shallow (< 10 m).

Relationships between water temperature and bass mortality in Idaho were similar to those observed in the southeastern United States. We found low initial mortalities (< 2%) below 18°C and variable at higher temperatures (Figure 2). Schramm et al. (1985) reported low mortality at temperatures below 20°C and variable mortalities at warmer temperatures.

Our findings suggest some important considerations for managers, tournament personnel, and participants interested in maximizing post tournament bass survival. Tournament participants are typically required to have circulating live wells but their effectiveness can vary among boats (Schramm et al. 1985; Bruce Rieman, Idaho Department of Fish and Game, pers. obser.). Since we found a significant correlation between tournament catch and initial mortality, we believe the higher mortalities probably occur when more fish are crowded in live wells. This suggests that some restrictions on numbers of fish retained in live wells should be considered, especially when temperatures exceed 18–20°C.

Another consideration to reduce mortality is to regulate the fishing day length, which is generally determined by tournament officials. The positive correlation between tournament day length and mortality suggests that longer fishing hours can result in higher initial mortalities. Seidensticker (1974) also suggested that length of confinement in a live well could be a significant mortality factor. Managers should consider time restrictions on tournaments especially when tournaments are scheduled when water temperatures exceed 18–20°C.

Our results generally agree with those of researchers in the south that fish mortalities associated with bass tournaments probably do not represent a significant impact to bass populations in larger waters such as the main river reservoirs. In smaller waters, however, a loss of 25% or more of the bass harvested in tournaments could have deleterious effects, especially if population abundance is low. Rieman (1983) showed that a single tournament may remove up to 10% of the bass present in small (< 500 ha) lakes. Managers should consider restrictions on certain tournaments. Controlled studies to identify and quantify the magnitude and causes of mortality or tournament caught bass may provide additional information which would be valuable to fishery managers.

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OBSERVATIONS ON INDUCED MATURATION AND SPAWNING OF ORANGEMOUTH CORVINA [1]

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Orangemouth corvina, *Cynoscion xanthulus,* were induced under laboratory conditions to mature sexually using photoperiod and temperature cycling, and spawn using abrupt (2–7 d) temperature fluctuations (2–5° C). Twenty-one temperature fluctuation trials conducted while photoperiods were 14 to 9 h light resulted in nine spawns of which seven provided fertilized eggs. Two spawns occurred after temperature reductions and two spawns spontaneously occurred with no temperature manipulation. Spawns produced 25,400–1,643,000 eggs with viability ranging from 0–85.3%.

INTRODUCTION

The orangemouth corvina, *Cynoscion xanthulus,* is an important sport fish in the Salton Sea, California (Whitney 1961, Collins 1981, Black 1985), and shows promise for stocking under wide salinity ranges (Lasker et al. 1972, Prentice 1985). However, reproduction in this species is restricted to a much narrower salinity range. Because of reduced freshwater inflow and high water evaporation rates, salinity is expected to increase in the Salton Sea, which may reduce the orangemouth corvina population unless more intensive management (e.g., hatchery stocking) is initiated. However, management is currently limited by little knowledge of orangemouth corvina reproductive biology.

Orangemouth corvina sexual development, but not spawning, has been laboratory-induced using photoperiod and temperature cycles which mimicked Salton Sea conditions (Prentice and Colura 1984). A combination of photoperiod and temperature cycling and gonadotropin injection has resulted in limited laboratory spawning success. Both human chorionic gonadotropin (Texas Parks and Wildlife Department, Palacios, Texas, unpublished data) and pregnant mare serum (G. Lattin, Occidental College, Los Angeles, California, pers. comm.) have induced ovulation and spawning. Gonadotropin therapy can presumably be refined to provide predictable and consistent spawning, but provides little information about natural spawning stimuli.

Schwassman (1971) and Powles (1981) reported that temperate bony fishes spawn largely according to day length and water temperature. Natural changes in day length during an annual cycle are regular and gradual while temperature can have great diurnal variation. Red drum, *Sciaenops ocellatus,* a sciaenid related to orangemouth corvina, is currently matured and spawned by

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simulating natural photoperiod and temperature cycles (Arnold et al. 1977, Roberts et al. 1978). Occasionally, matured red drum, residing under photoperiod and temperature cycle spawning conditions, require a 1.0° C/day, for up to 6 days, temperature fluctuation to induce spawning (Roberts 1987). This paper reports observations on laboratory-induced gonadal maturation of orangemouth corvina using photoperiod and temperature conditioning, and spawning using temperature fluctuations of 2–5° C.

METHODS

Seventy Salton Sea orangemouth corvina were collected in October 1981 as subadults ($\leq$ 345 mm total length, TL), transported to Texas and reared to adult size ($\geq$ 620 mm TL) (Prentice and Colura 1984). For this study, subsets of these fish were housed at Heart of the Hills Research Station (HHRS), Ingram, Texas (four males and three females) and Perry R. Bass Marine Fisheries Research Station (MFRS), Palacios, Texas (four males and three females). Fish growth, age and sizes were similar at both locations.

Gonadal development was induced by regulating photoperiod and water temperature to simulate Salton Sea seasonal variations. However, duration (number of days) of each photoperiod/temperature regime at each location varied (Figure 1). Fish were sampled approximately once per month during summer and fall to monitor sexual development. All fish sampled (four males and three females at HHRS; four males and three females at MFRS) were anesthetized before handling with Hypno (active ingredient: dimethylketone alpha methyl quinoline, Jungle Laboratories Corp, Cibolo, Texas) (Prentice and Colura 1984). Intraovarian samples were collected by catheterization (Hoff et al. 1972). Ova were examined for yolk deposition (Roberts et al. 1978) and measured to the nearest 0.01 mm with an ocular micrometer at either 40X or 100X magnification. Males were considered sexually mature when milt was expressed by abdominal massage.

Males began spermiation at 14–15 h light and $\geq$28 C. Mean vitellogenic ovum diameter measured $\geq$0.37 mm approximately 2 months after reaching peak daylength and temperatures.

Twenty-one temperature fluctuation trials were attempted when temperatures were 25–30° C (Table 1). Photoperiods were 12 —9 h light for 18 trials and 14 h light for three trials. Trials were accomplished by reducing temperatures 2–5° C in 24–72 h and returning to the starting temperature ($\pm$ 1° C) in 24–96 h. Fish were exposed to a temperature fluctuation trial followed by additional trials until spawning occurred.

Number of eggs spawned was estimated by volumetric subsampling as described by Bagenal and Braum (1971). Percent fertilization was determined by examining three samples of approximately 100 eggs each for mitotic division. Specific mitotic stages were not determined because of the rapid development of warm water sciaenid eggs at 25–30° C.

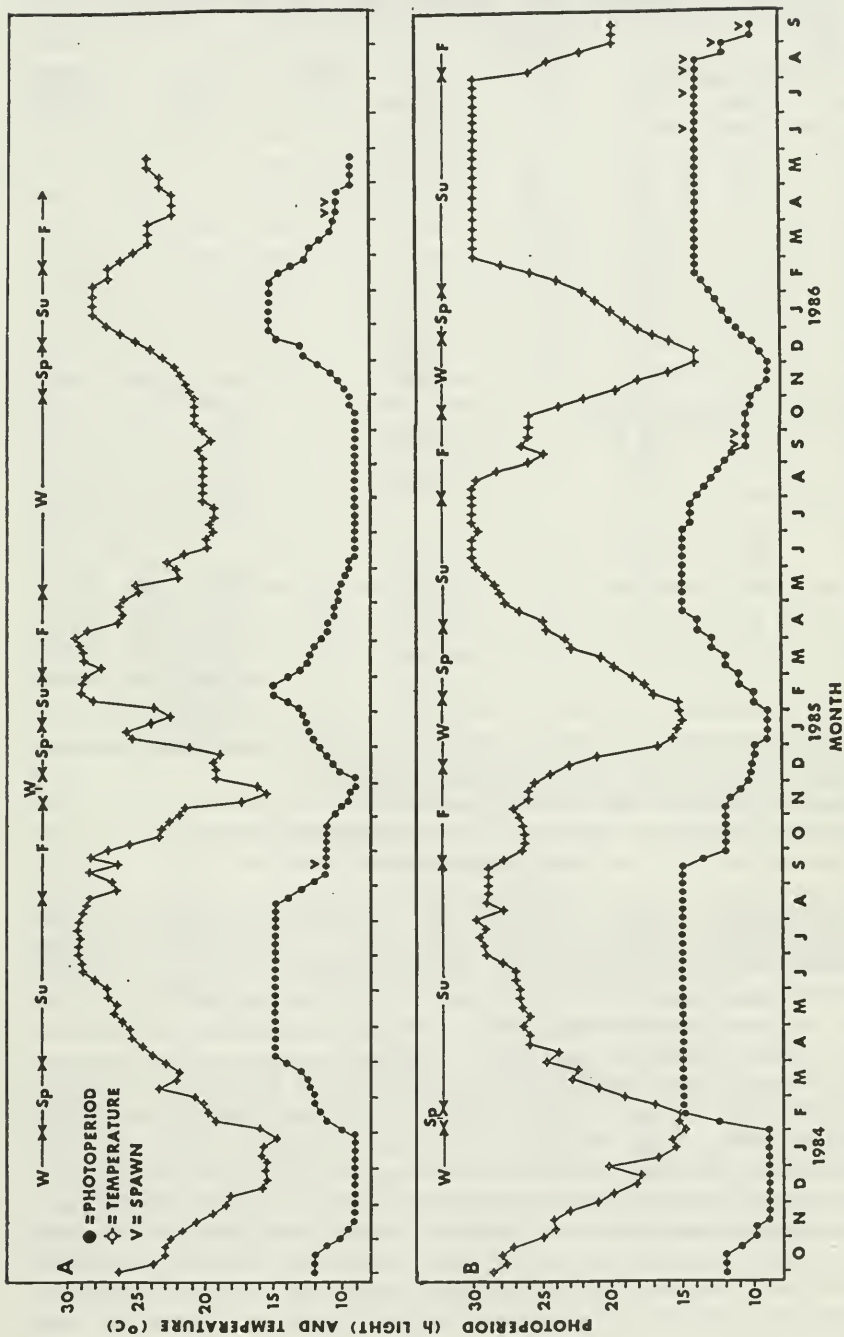

FIGURE 1. Photoperiod (h light) and water temperature (weekly mean °C) regimes used to induce gonadal development in orangemouth corvina at Heart of the Hills Research Station (A), Ingram and Perry R. Bass Marine Fisheries Research Station (B), Palacios, Texas, October 1983 through September 1986. Spawns and simulated laboratory winter (W), spring (Sp), summer (Su) and fall (F) are indicated.

TABLE 1. Orangemouth Corvina Spawning Response to Laboratory Photoperiod and Temperature Conditioning in Combination with Temperature Fluctuation Spawning Cues. Fluctuations Included Reducing Temperatures 2–5° C in 24–72 h and Returning to the Starting Temperature ±1° C) in 24–96 h.

Temperature fluctuation initiation date	*Photoperiod (h light)*	*Initial temperature (° C)*	*Temperature fluctuation decrease (° C)*	*Spawn occurrence (no/yes, date)*	*Spawning temperature (° C)*	*Number of eggs (± SD)*	*Percent fertilization (± SD)*
Heart of the Hills Research Station							
9-18-84	12	28	3.0	yes, 9-20-84	27	–[a]	0
9-23-84	12	29	3.0	no			
10-10-84	11	28	4.0	no			
6-12-85	9	28	4.0	no			
6-19-85	9	29	4.0	no			
6-26-85	9	27	3.0	no			
7-01-85	9	28	4.0	no			
7-08-85	9	27	5.0	no			
7-17-85	9	26	4.0	no			
3-19-86	12	25	3.0	no			
3-25-86	11	26	3.0	no			
3-31-86	10	25	3.0	yes, 4-02-86	23	1,643,000 ± 344,000	0.3 ± 0.2
4-07-86	10	26	3.0	yes, 4-12-86	24	364,200 ± 51,000	1.2 ± 0.7
Perry R. Bass Marine Fisheries Research Station							
9-09-85	12	29	5.0	yes, 9-15-85	25	433,000 ± 10,000	–[b]
9-16-85	12	26	3.0	no			
9-23-85	12	25	2.0	yes, 9-27-85	27	723,500 ± 86,000	82.7 ± 2.1
						355,700 ± 16,000 [c]	25.7 ± 4.2
9-30-85	12	27	3.5	no			
10-07-85	12	27	3.0	no			
6-11-86	14	30	4.0	yes, 6-17-86	30	710,000 ± 324,000	29.9 ± 6.0
7-10-86	14	30	5.0	yes, 7-16-86	30	1,442,000 ± 75,900	70.7 ± 5.4
8-07-86	14	30	3.0	yes, 8-08-86	27	953,000 ± 61,700	0
–[d]	14	30	0.0	yes, 8-20-86	30	1,230,600 ± 79,800	85.3 ± 7.6
8-26-86	12	32	6.0	yes, 8-31-86 [e]	26	614,200 ± 156,600	13.0 ± 6.6
						447,300 ± 197,400	13.0 ± 6.6
				yes, 9-01-86 [e]	25	408,600 ± 90,700	0
–[d]	10	22	0.0	yes, 9-11-86	22	25,400 ± 1,100	0

[a] Spawned eggs sank and were not concentrated in the collection chamber to allow estimation of number.
[b] Eggs not removed from collection chamber until after hatching occurred.
[c] Eggs bypassed collection chamber and were removed from filter system.
[d] Spawns occurred spontaneously with no temperature manipulation.
[e] Spawns occurred after temperature reduction of 6° C without a return to initial temperature.

OBSERVATIONS

Thirteen spawns occurred between 1984 and 1986 with individual spawn sizes ranging from 25,400 to 1,643,000 eggs (Table 1). Nine of the 13 spawns occurred in response to temperature fluctuation trials, two spawns occurred after a temperature reduction without return to a starting temperature and two spawns occurred spontaneously with no temperature manipulation. Only nine spawns produced fertilized eggs (Table 1) although summer and fall photoperiods (15–9 h light) and temperature ($\leq$ 28° C) always elicited drumming and courtship behavior by males. With exception of the 20 Aug 1986 spawn, spawns resulting in fertilized eggs occurred 1–7 d after temperature reduction from initial 25–30 ° C temperatures. Photoperiod was 14–10 h light for all spawns.

Experimentally induced spawning of orangemouth corvina using environmental cues suggests a summer and fall spawning season rather than, or in addition to, spring and early summer as suggested by Whitney (1961). Laboratory spawning under summer and fall conditions agrees with 1984 ichthyoplankton data from the Salton Sea. Orangemouth corvina larvae ($\geq$ 2.5 mm TL) were

found July through October, but not in May or November (G. Jordan, Occidental College, Los Angeles, California, pers. comm.). However, 1987 data indicate larvae present in the western portion of the Salton Sea from April through August (M. Matsui, Occidental College, Los Angeles, California, pers. comm.).

The reproductive stage is the most sensitive of all fish life cycle functions to physiological stress and little physiological reproductive adaptation to temperatures outside a normal range for a fish can be expected (Gerking 1980). Therefore laboratory spawning results should reflect deviations from natural or required conditions. Spring, early summer and fall photoperiod and temperature conditions were generally similar at both HHRS and MFRS in all years (Figure 1). However, gonadal maturation occurred at both laboratories only during summer. Summer cycle was simulated at MFRS in 1985 and 1986 with a photoperiod $\geq$ 14 h light for $\geq$10 wk and relatively stable 30° C temperature for $\geq$ 9 wk (Figure 1). Summer conditions during the same years were maintained at HHRS with a photoperiod $\geq$ 14 h light for $\leq$ 6 wk and temperatures ranging from 26.5 to 29.0° C (Figure 1). Spawns with high percent fertilization occurred at MFRS but not at HHRS in 1985 and 1986 (Table 1). These observations suggest that stable summer conditions are important for sexual maturation before spawn triggering in late summer and fall.

Why fluctuating temperatures appeared to trigger spawning in orangemouth corvina is unclear. Initial spawns in all study years did not occur until temperature fluctuations were initiated, although spawning did occur later in the 1986 spawning period without temperature fluctuations. Short-term changes in laboratory temperature may represent environmental temperature fluctuations caused by weather conditions or normal diurnal effects. Since spawning did occur twice without temperature fluctuations and twice with temperature reduction only, it appears that temperature fluctuations are not always required for spawning, but may stimulate more frequent and/or successful spawning. In addition, multiple temperature fluctuation exposures may be necessary to ultimately cause spawning. Increased spawning success as brooder age increased indicate that fish were marginally eligible for spawn inducement in 1984 and 1985. Consistent spawning response and spawn sizes in 1986 suggest that artificial propagation of orangemouth corvina is feasible.

ACKNOWLEDGMENTS

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FOOD HABITS, SEASONAL ABUNDANCE, SIZE, AND SEX OF THE BLUE SHARK, *PRIONACE GLAUCA*, IN MONTEREY BAY, CALIFORNIA.[1]

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One hundred fifty blue sharks, *Prionace glauca*, were caught in Monterey Bay, California, from June through October, 1974–1977. Greatest catch rates occurred in August, a time of relatively high sea surface temperatures (16°C). Blue sharks were 960 to 2040 mm (mean = 1600, C.I. = 20 mm) in total length, and an average 15.7 kg (C.I. = 1.4 kg) in weight. Females (n = 121) were significantly more numerous in the catch than males (n = 27). Blue sharks primarily fed on abundant, pelagic prey. The primary prey in the stomachs of 146 blue sharks were euphausiids, mostly *Thysanoessa spinifera;* northern anchovy, *Engraulis mordax;* Pacific hake, *Merluccius productus;* spiny dogfish, *Squalus acanthias;* Pacific herring, *Clupea harengus pallasi;* and five genera of cephalopods. Blue sharks probably fed throughout the day, but most cephalopods and fishes were eaten when the prey migrated near the surface at night.

INTRODUCTION

The blue shark, *Prionace glauca*, is common in the epipelagic zone of the world's oceans. It is the most abundant pelagic shark in the central North Pacific, found as far north as the Gulf of Alaska (lat 57°N) during the months of August and September and between 20°N and 40°N during winter (Strasburg 1958, Neave and Hanavan 1960). Seasonal migrations of blue sharks are typically associated with changes in water temperature (Beckett 1970, Stevens 1976) and perhaps food abundance (Strasburg 1958). Blue sharks inhabit water with sea surface temperatures (SST) of 11 to 27° C, worldwide, but are commonly found in 11 to 17° C waters in the Pacific (Neave and Hanavan 1960; Gubanov and Grigor'yev 1975). As the oceanic water warms in the northern hemisphere, blue sharks move northward and inshore, with large females preceding smaller males and females (Stevens 1976). The larger adult males are found farther offshore.

Blue sharks have become the target of a fishery off California (Holden 1973, Ronsivalli 1978, Cailliet and Bedford 1983), yet, with the exception of studies by Sciarrotta and Nelson (1977) and Tricas (1979), little data exist on the natural history of this important nearshore predator.

Blue sharks prey upon pelagic schooling fishes such as herring, *Clupea harengus;* sardine, *Sardinops* spp.; saury, *Cololabis saira;* jack mackerel, *Trachurus symmetricus,* and numerous species of cephalopods (Bigelow and Schroeder 1948, Strasburg 1958, LeBrasseur 1964, Stevens 1973, Tricas 1979).

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The potential impact of their foraging on commercially important fishes is unknown, as are the changes that may occur in the food web as more blue sharks are harvested.

With these deficiencies of information in mind, this paper describes the food habits, lengths, sexes, and seasonal occurrence of blue sharks in Monterey Bay, California. Particular attention is given to predation by blue sharks on prey species which support local fisheries, such as northern anchovy, *Engraulis mordax;* Pacific hake, *Merluccius productus*; and market squid, *Loligo opalescens*.

MATERIALS AND METHODS

Blue sharks were collected and observed in Monterey Bay, California (ca. lat 36°50′N, long 121°50′W). Monterey Bay is bisected by a submarine canyon that is 500 m deep within 8 km of the coastline. The primary collection area was located in the middle of the bay over the submarine canyon (Figure 1).

Blue sharks were collected on a weekly basis, weather permitting, June through October, 1974–1977. Relative abundance of blue sharks was recorded during monthly fish collection cruises in Monterey Bay from 1976 to 1977 (Morejohn et al. 1978). Sharks were caught between 0700 and 1300 h on 90-m longlines (1974 and 1975; 20 hooks) or five hooks with 5-m leaders fished directly from a 4.5 m Boston Whaler (1976 and 1977). Hooks were baited with northern anchovy or market squid. The bait was distinctively cut to allow its identification from actual prey in the stomach. A perforated gallon container of macerated anchovy was used to attract sharks.

Weight of shark (to the nearest 0.5 kg), total length (TL measured to the nearest mm), and sex were recorded. Sex was not determined for two blue sharks, and length was not recorded for one individual. A Student's t-test was used to test differences between TL of males and females, and an analysis of variance test was used to test average TL among years (Sokal and Rohlf 1969). The weight/length relationship was calculated using a geometric mean functional regression after the data were logarithmically transformed (Ricker 1975). Stomachs were removed and contents sieved through a 0.5 mm screen and fixed in 10% buffered formalin for two days. The contents were stored in 40% isopropyl alcohol.

State of digestion and fullness of stomach contents were scored on a subjective scale of 1 to 4 as described by DeWitt and Cailliet (1972). Prey items were identified to the lowest possible taxon. Cephalopod beaks were identified using a key by Clarke (1962), a pictorial guide by Pinkas et al. (1971), and a reference collection at Moss Landing Marine Laboratories. Otoliths were identified by J. E. Fitch (Calif. Dept. Fish and Game, deceased) and the author.

Prey items from each stomach were counted, measured, and their volume determined by displacement in water. When prey were represented only by otoliths or beaks, counts were determined by the largest number of right or left otoliths, or greatest number of upper or lower beaks. Standard length (SL) of fish eaten by blue sharks was determined by measuring intact fishes or otoliths found in the stomachs. Fish length was estimated by entering otolith length into a linear regression of otolith length to fish length (Harvey 1987). Size of ingested market squid was determined from direct measurements of the dorsal

mantle length; when only beaks were available, three morphometric measurements of upper and lower beaks were used to estimate length from regressions reported by Kashiwada et al. (1979). The sizes of other cephalopod species were not estimated.

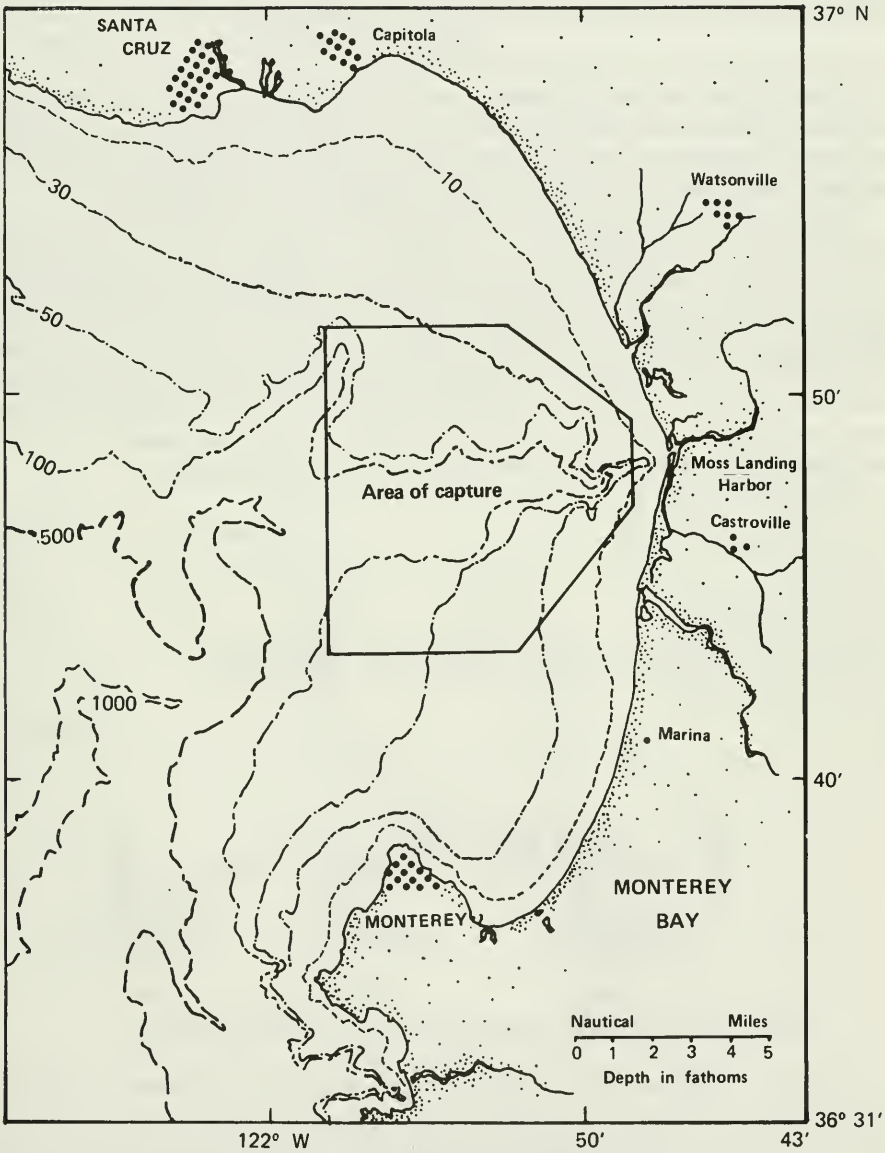

FIGURE 1. Collection area for blue sharks in Monterey Bay, California.

The importance of each prey species was evaluated by calculating an index of relative importance (IRI), IRI = (%V + %N) X %FO, where %V is percent volume, %N is percent number, and %FO is percent frequency of occurrence

(Pinkas et al. 1971). All blue sharks, except those with everted stomachs, were included in calculations of IRI values. The adequacy of the number of samples for stomach analyses was verified by plotting the cumulative number of prey categories against the randomly pooled number of fish samples for each year (Hurtubia 1973). The Spearman rank correlation test was used to test changes in dietary ranking between the 1976 and 1977 collections.

RESULTS

One hundred and fifty blue sharks were collected; 30 in 1974 and 1975, 54 in 1976, and 66 in 1977. Sharks were caught as early as 25 June and as late as 17 October, although occasional sightings occurred throughout the year. The highest catch rates occurred in August (4 sharks/hr) 1976 and 1977.

Sharks were 960 to 2040 mm TL (mean–1600 mm, SD–200 mm; Figure 2). There appeared to be three size modes for the combined and 1977 data. Only two modes were apparent for the 1976 data, when the smaller size classes (less than 1200 mm) were not captured. There was no significant difference in the average total length of males and females ($t = 1.7$, $P > 0.01$) or of sharks collected in different years ($F = 3.1$, $P > 0.01$). Blue sharks caught in Monterey Bay averaged 15.7 kg (SD–1.4) in weight, with a range of 3.6 to 38.1 kg. There was no difference in mean weight between males and females, so the weight-length relationship was described by the single equation:

$$\text{body weight} = 2.57 \times 10^{-9} (\text{TL})^{3.05} (r^2 = 0.72).$$

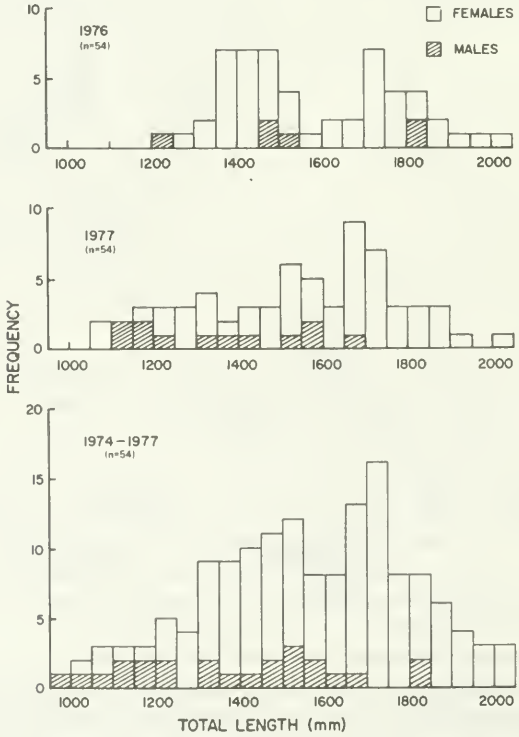

FIGURE 2. Frequency distributions of total lengths for blue sharks caught in 1976, 1977, and all years (1974–1977) combined.

A significantly greater number of females (n = 121) than males (n = 27) was collected for all years combined ($X^2 = 59.7$, $P < 0.005$). No females were pregnant, and all were judged to be immature. Only one female (1800 cm TL) was observed with teeth marks or scars on the back and sides, presumably a result of mating behavior (Stevens 1974, Pratt 1979). The left ovary of all females was poorly developed or lacking, as in all carcharhinids, while the right ovary was large and globular (Pratt 1979).

Stomach analyses were performed on 150 specimens of which 23 (15.3%) had empty stomachs, four (2.7%) had everted stomachs (which were not included in the analyses), and two (1.3%) contained only unrecognizable, digested material. Thirty-three prey categories were recognized. A plot of cumulative number of prey categories against number of stomachs examined in 1976 indicated 30 samples would adequately depict the diet of blue sharks in that year. In 1977, a cumulative frequency curve approached an asymptote at 60 stomachs, but infrequent prey items (< 1% frequency of occurrence) contributed to this increased estimate. Stomachs with contents were usually less than half full, and prey were in an advanced state of digestion (feeding state "a", not full or recent, Figure 3). The second most common feeding state indicated stomachs were not full but feeding was recent.

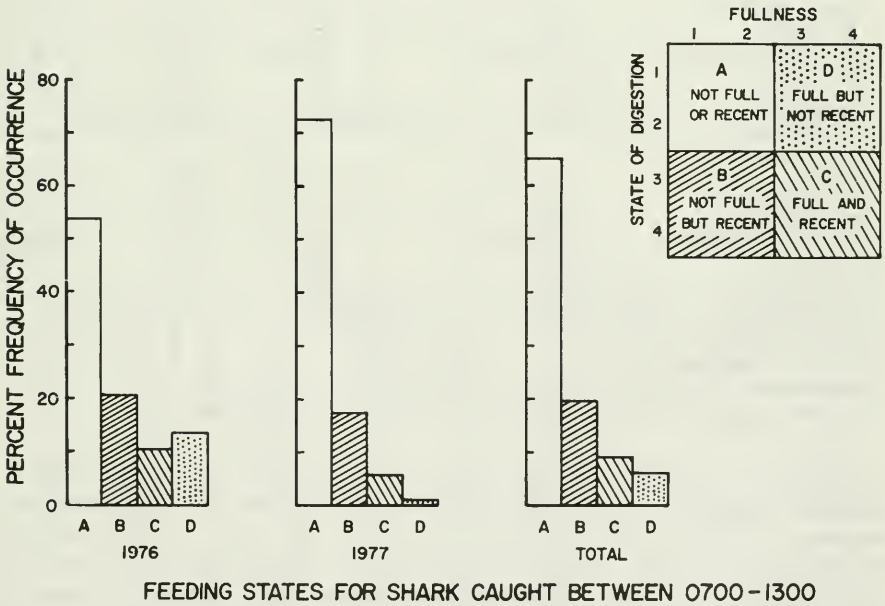

FIGURE 3. Feeding states of 121 blue sharks caught between 0700 and 1300 hrs, 1974–1977.

The most important prey items of blue sharks in all years in Monterey Bay were euphausiids, primarily *Thysanoessa spinifera*; northern anchovy; Pacific hake; spiny dogfish, *Squalus acanthias*; Pacific herring, *Clupea harengus pallasi*; and five genera of cephalopods (Table 1). Euphausiids and northern anchovy were the most numerous items and constituted the most important portion of the diet by volume.

TABLE 1. Prey Taxa of 146 Blue Sharks from Monterey Bay, California for 1976, 1977, and All Years Combined (1974–1977) [1]

Prey Species	*Total*				*IRI Rankings*		
(Common name)	*%N*	*%V*	*%FO*	*IRI*	*All*	*1976*	*1977*
Fishes							
Engraulis mordax (northern anchovy)	1.5	15.7	16.4	282.1	2	2	3
Merluccius productus (Pacific hake)	0.2	8.5	16.4	142.7	4	4	4
Squalus acanthias (spiny dogfish)	0.2	12.1	8.9	109.5	5	3	2
Clupea harengus pallasi (Pacific herring)	0.1	3.4	2.7	9.5	14	9	–
Citharichthys sordidus (Pacific sanddab)	0.1	2.2	2.1	4.8	16	6	–
Porichthys notatus (plainfin midshipman)	<0.1	1.6	2.1	3.4	17	12	24
Sebastes paucispinus (bocaccio)	<0.1	1.5	2.1	3.2	19	–	10
Anoplopoma fimbria (sablefish)	<0.1	1.9	1.4	2.7	20	–	12
Sebastes goodei (chilipepper)	<0.1	2.1	0.7	1.5	22	–	19
Stenobrachius leucopsarus (northern lampfish)	<0.1	1.3	0.7	0.9	23	20	–
Genyonemus lineatus (white croaker)	<0.1	1.1	0.7	0.8	24	–	21
Syngnathus californiensis (kelp pipefish)	<0.1	0.9	0.7	0.6	25	–	22
Lyopsetta exilis (slender sole)	<0.1	0.4	0.7	0.3	26	22	–
Chilara taylori (spotted cusk-eel)	<0.1	0.2	0.7	0.1	31 *	23	–
Lampetra tridentatus (Pacific lamprey)	<0.1	0.2	0.7	0.1	31 *	–	26
Sebastes spp. (unidentified rockfishes)	<0.1	0.2	0.5	<0.1	33	–	20
unidentified teleosts	0.7	8.1	6.9	60.7	8	11	14
unidentified elasmobranchs	<0.1	1.3	1.4	1.8	21	17	16
Cephalopods							
Loligo opalescens (market squid)	0.3	2.1	13.7	32.9	10	5	7
Octopoteuthis deletron	0.1	2.0	7.5	15.8	13	19	13
Vampyroteuthis infernalis	0.1	0.9	6.2	6.2	15	14	15
Onychoteuthis borealijaponicus	0.1	0.9	3.4	3.4	18	18	–
Argonauta pacifica	<0.1	0.3	0.7	0.2	28 *	–	23
Dosidicus gigas (jumbo flying squid)	<0.1	0.3	0.7	0.2	28 *	–	25
Octopus spp.	0.4	2.8	21.2	67.8	6	7	6
Gonatus spp.	0.2	3.7	11.6	45.2	9	10	9
Histioteuthis spp.	0.2	1.7	10.3	19.6	12	16	8
unidentified cephalopods	0.2	5.7	10.3	60.8	7	15	11
Crustaceans							
Thysanoessa spinifera	82.6	8.2	10.3	935.2	1	1	5
Pandalus jordani	<0.1	0.3	0.7	0.2	28 *	21	–
Euphausia pacifica	<0.1	0.2	0.7	0.1	31 *	–	18
unidentified euphausiids	12.4	4.9	13.0	224.9	3	13	1
Miscellaneous							
unidentified plant	0.3	3.7	8.2	32.8	11	8	17

[1] Percent number (%N), percent volume (%V), percent frequency of occurrence (%FO), and index of relative importance (IRI) of prey taxa found in blue shark stomachs are given for the total catch.

* tied ranks

– Not found

Number, volume, and frequency of occurrence of the major prey categories (fishes, cephalopods, and crustaceans) remained relatively constant throughout all four years of sampling (Figure 4). Prey rankings, according to IRI values, were not significantly different between 1976 and 1977 ($r_s = 0.07$, $P > 0.05$). In general, prey which were important in the diets of blue sharks in one year were important in other years.

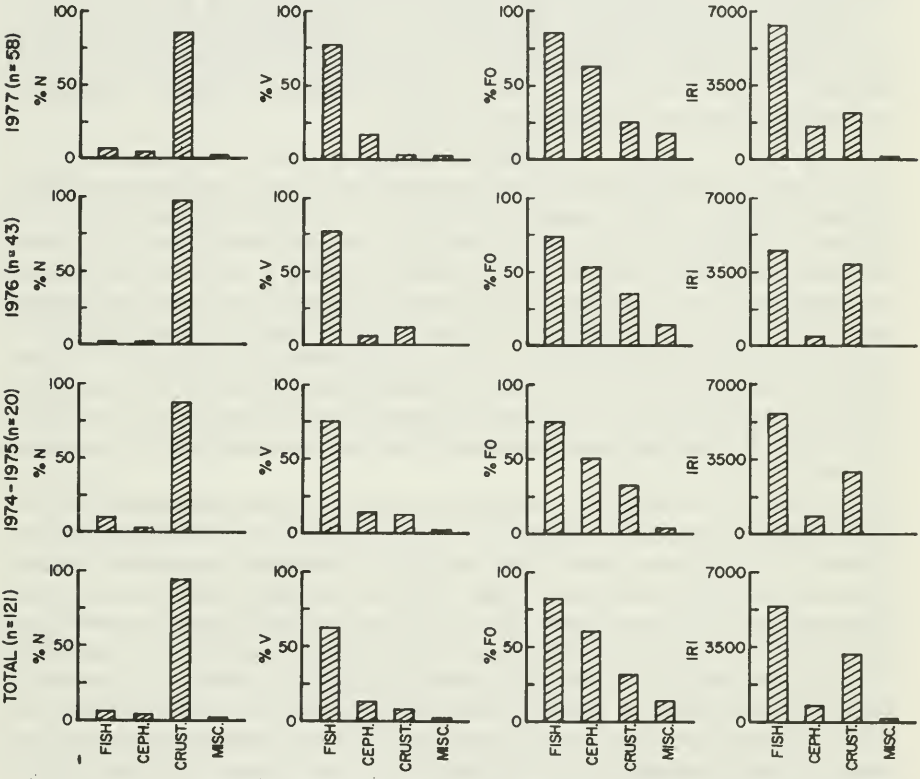

FIGURE 4. Comparison of major prey categories by percent number (%N), percent volume (%V), percent frequency of occurrence (%FO), and index of relative importance (IRI) for 1974–1977.

Northern anchovy were present in 24 (16%) of the 146 blue shark stomachs, and averaged 7.3 fish per stomach (range: 1–46). The average size of anchovy ingested was 10.5 cm SL (SD – 3.2). Blue sharks fed upon anchovies mainly in July and August; only two sharks caught in September and October contained this species. Pacific hake were consumed by 24 (16%) of the blue sharks analyzed from Monterey Bay. Hake were usually represented in the stomachs by otoliths, but when they occurred undigested there was only one fish per shark. Ingested hake, based upon otolith length, averaged 31.2 cm SL (SD – 11.1, range 10.0 — 50.6 cm). Spiny dogfish were present in 12 (8%) blue sharks, and averaged 41.4 cm TL (SD – 21.6, range 20.5 — 80.4 cm TL). Only once was more than one (four) dogfish found per stomach.

Two species of euphausiids were identified as blue shark prey, *T. spinifera* and *Euphausia pacifica*. *Thysanoessa spinifera* occurred in 15 (10%) stomachs,

whereas *E. pacifica* was present in only two (1%). On 26 July 1976, nine of 12 sharks contained *T. spinifera*, in numbers ranging from 1 to 2179 individuals. Euphausiids were consumed by blue sharks only in July and August, a time when euphausiid swarms were observed at the surface (Harvey 1979). Blue sharks were observed swimming through these euphausiid swarms with mouths agape in six of 11 swarms observed in this study.

Nine genera of cephalopods were identified from blue shark stomachs (Table 1). Other than market squid, the majority of cephalopods were represented only by beaks. Market squid appeared in 20 (14%) of the sharks sampled, and averaged 9.6 cm (SD – 1.0) in dorsal mantle length. The greatest number of market squid ingested at one time was seven.

DISCUSSION

Blue sharks, although present in Monterey Bay in low numbers throughout the year (Harvey 1979), became common as SST increased during the late summer and early fall (Bolin and Abbott 1962). Most (84%) blue sharks were females. The SST in Monterey Bay ranged from 14 to 17°C at the time of increased blue shark abundance; SST started to rise in July and peaked between August and October. In 1976, SST in the middle of the Bay ranged from 9.8°C in June to 16.6°C in August (Lasley 1976). Surface temperatures in 1977 ranged from 9.8°C in April to 15°C in October (Chinburg and Lasley 1977). Movements of female blue sharks appear to be correlated with SST between 14 and 17°C, as indicated by their increased abundance from July through October, when the highest SST were recorded.

Blue shark sex segregation, based upon a response to water temperature, has been discussed by authors working in other geographical areas (Suda 1953, Stevens 1973, Gubanov and Grigor'yev 1975); however, no reason for the segregation has been proposed. Tricas (1977) collected blue sharks near Santa Catalina Island, California, from March 1975 to March 1976 and recorded the highest SST in August and September. In conjunction with this warming trend, he found that male blue sharks represented a greater portion of the catch, whereas the numbers of females were reduced. Females were absent in the catch in August, but dominated the southern California catch in December and January. The preponderance of females in July and August in Monterey Bay suggests that movements of female blue shark from southern to northern California maybe influenced in part by water temperature.

The majority of blue sharks caught in this study were 1300 to 1900 mm TL, less than six yr of age, and judged to be sexually immature (Harvey 1979, Cailliet et al. 1983). Blue sharks attain maturity at approximately 1800 mm fork length and seven yr (Pratt 1979). Stevens (1973) collected blue sharks in the nearshore waters of England and found most were 1500 to 2300 mm TL and immature. Blue sharks captured in the central North Pacific were 2200 to 2600 mm TL and primarily mature individuals (Strasburg 1958). These results imply that immature blue sharks live in nearshore waters whereas adults are located farther offshore. Pratt (1979), however, found adult males in breeding condition over the continental shelf of New England.

Few blue sharks caught in Monterey Bay had fed between 0700 and 1300 h. Most prey items in blue shark stomachs were represented by hard parts that remained after digestion (e.g. fish otoliths and eye lenses, cephalopod beaks, crustacean carapaces and eyes). Blue sharks were observed actively feeding

only on euphausiids. Daytime feeding by blue sharks near the surface is probably restricted to anchovies, euphausiids, and market squid; however, they may dive deep to consume other prey species. During the night, blue sharks may consume vertically migrating nekton such as hake, lanternfishes, cephalopods, and euphausiids. Telemetered blue sharks off southern California increased their feeding activity in late evening and night (Sciarrotta and Nelson 1977). Increased feeding activity at night has been reported for a number of tropical carcharhinids (Nelson and Johnson 1970). Some aspects of the feeding ecology of blue sharks in Monterey Bay may be revealed by reviewing the natural history of the most important prey.

Northern anchovies are one of the most abundant fishes in the northeastern Pacific (Baxter 1967). Although eggs and larvae occur 480 km off the coast, the greatest densities of northern anchovies are found within 37 km of shore, over deep-water basins (Ahlstrom 1967, Smith 1972, Mais 1974). Northern anchovies in California exhibited vertical migrations to the surface during the evening (Baxter 1967), although Mais (1974) reported low-density schools of anchovies near the surface during daylight. Anchovies were one of the most abundant fishes collected in midwater trawls made during the summer in Monterey Bay (Cailliet et al. 1979). Anchovies were ranked as the most important fish prey of blue sharks in Monterey Bay because they were the most numerous and least digested. This may be the result of the daytime schooling pattern and consequent availability of anchovies to blue sharks at the time of shark collection.

Pacific hake were well digested in samples of blue sharks caught during morning hours, indicating this species was probably eaten during the evening. In the North Pacific, the greatest concentrations of hake occur between British Columbia and Baja California (Alverson and Larkins 1969). In Monterey Bay, Pacific hake was the second most abundant and third most frequently occurring fish in midwater trawls conducted deeper than 64 m during summer (Cailliet et al. 1979). Diel vertical migrations of hake occur in response to the vertical migration of euphausiids, their primary food source (Stauffer 1985). During daylight, hake are concentrated in dense schools between 100 and 250 m depth; at night they disperse and are found from the surface down to 20 m depth.

Although spiny dogfish were the third most frequently occurring fish fed upon by blue sharks, they were not caught in either midwater trawls or purse-seine hauls in Monterey Bay (Cailliet et al. 1979).

Predation on benthic species of fishes, such as slender sole, *Lyopsetta exilis,* and spotted cusk-eel, *Chilara taylori,* indicate that blue sharks occasionally fed near the bottom. Many of the other species of fishes eaten could have been consumed throughout the water column.

Blue-shark predation on euphausiids has not been reported previously. Euphausiid swarms were observed at the water's surface on 11 occasions at the mouth of Monterey Bay Canyon between July and August 1975–1976 (Harvey 1979). Surface swarms of *T. spinifera* and *E. pacifica* have been observed by others along the California coast; most swarms were observed from July to September (Boden et al. 1955, Brinton 1962, Smith and Adams 1988). Brinton (1962) found no evidence that *T. spinifera* migrated vertically, and he thought they were restricted to the upper 100 m. *Euphausia pacifica* is found mainly in the upper 280 m, moving upwards at night to within 140 m of the surface

(Brinton 1962). Euphausiids probably are eaten opportunistically only when they are present in swarms near the surface. Blue shark predation on euphausiids is probably infrequent because euphausiid swarms are temporally and spatially limited. All euphausiids found in blue shark stomachs were fresh, and therefore, not secondary prey of hake.

Predation on cephalopods by blue sharks is well documented and many of these cephalopods are considered deep-water species (Le Brasseur 1964, Stevens 1973, Tricas 1979). *Octopoteuthis deletron, Histioteuthis* spp., and *Onychoteuthis borealijaponicus* all undergo vertical migration that brings them near the surface at night (Pearcy 1965, Young 1972, Roper and Young 1975). *Vampyroteuthis infernalis,* however, may remain below 800 m throughout the day and night (Lu and Clarke 1975, Young 1978). Many species of gonatid squids are found mid-water and undergo some vertical migration; *Gonatus berryi* and *G. onyx* have been captured in Monterey Bay (Anderson 1978) and probably are the species occurring in blue shark diets.

Most cephalopods in blue shark stomachs were represented by their beaks; only *L. opalescens* was found in early stages of digestion. *Loligo opalescens* is found from British Columbia to the southern tip of Baja California and is mainly neritic (Fields 1965). Roper and Young (1975) speculated that market squid occurred near the bottom during the daylight, and moved upwards and dispersed during the night. Karpov and Cailliet (1978), however, found a peak in feeding activity of market squid from 1000 to 1200 h. Presumably, these squid had been feeding near the surface. Market squid spawn in shallow sandy areas in Monterey Bay and is the most frequently occurring pelagic organism in summer midwater trawls made in Monterey Bay (Cailliet et al. 1979). In southern California, blue sharks were observed moving towards shore in the evening and preying upon shoals of *L. opalescens* (Sciarrotta and Nelson 1977, Tricas 1979). Blue sharks probably consume most cephalopods at night and near the surface, but may eat some at greater depths throughout the day. Cephalopod beaks, composed of chitin and resistant to digestion, can remain intact within a predator's stomach for long periods of time. Some cephalopods, therefore, may have been eaten before blue sharks moved into Monterey Bay. All cephalopod beaks, however, appeared intact and newly ingested.

Blue sharks eat a variety of prey and during their seasonal appearance consume northern anchovy, euphausiids, and market squid, which are the most prevalent food sources for many vertebrate predators in Monterey Bay (Morejohn et al. 1978).

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NOTES

THE CORTEZ ANGELFISH, *POMACANTHUS ZONIPECTUS*, RECORDED FROM SOUTHERN CALIFORNIA

The Cortez angelfish, *Pomacanthus zonipectus* (Gill), was originally described from a single specimen taken by Captain John M. Dow off "San Salvador" [=El Salvador] in the 1850's. It is the sister species of the Caribbean-western Atlantic French angelfish, *P. paru* (Bloch); the similarity, especially in the juvenile stage, has been noted by a number of researchers. *Pomacanthus zonipectus* is tropical, as is the family Pomacanthidae. The distribution for the species is given by Thomson, Findley, and Kerstitch (1979) in their treatment of "Reef Fishes of the Sea of Cortez" as ". . . ranges widely from the northern Gulf (Puerto Peñasco) and north of Bahia Magdalena (Bahía San Juanico) to Peru. It is a common fish on most shallow reefs in the Gulf."

Between March 1984 and October 1986, three Cortez angelfish were observed (one of which was collected) at three different localities off southern California. The unique circumstance surrounding each of the sightings (including the one capture) in and of itself would not allow adding the species, with reasonable confidence, to the California ichthyofauna. However the summation of these observations, the most recent of which was recorded on videotape (Figure 1), allows us to support the hypothesis that Cortez angelfish can occur as expatriates off southern California during certain oceanographic conditions.

FIGURE 1. Cortez angelfish on "Lost-and-Found Reef," San Diego Co., observed on 25 October 1986. Photograph transferred from video tape. Video by K. C. Wilson.

On 28 March 1984 an adult Cortez angelfish, measuring 216 mm SL (263 mm TL), was speared by Bradley Lockey off the Los Angeles breakwater in ca. 2.5 m of water. The specimen was then taken to Cabrillo Marine Museum, San Pedro, for identification, where it is now accessioned (CMM No. 87.10.1). Lloyd Ellis, Chief Aquarist at CMM, reported the capture to the senior author, who, although aware of anomalously warm water during this period (i.e., El Niño of 1982–84), and captures of tropical species off California (Lea 1984 and Lea and Vojkovich 1985), felt that in this case the occurrence of a Cortez angelfish in Los Angeles Harbor might be attributable to release by a long-range sportfishing vessel returning from Mexico or by a commercial or home aquarist. Cortez angelfish are commonly imported, high demand, marine aquarium fish and sell for $35 to $55 retail in pet and aquarium stores.

Approximately eight months later, on 15 November 1984, Dr. Bert Kobayashi, diving officer at University of California San Diego and a trained ichthyologist, observed an adult Cortez angelfish while on a dive at ca. 18 m in the Scripps branch of the La Jolla Submarine Canyon. The fish was sighted on three separate occasions at the same locale between the 15th and 17th but was neither photographed nor collected.

On 24 and 25 October 1986, John Duffy, Heidi Togstad, and Ken Wilson, research divers for the California Department of Fish and Game, while surveying an artificial reef off San Diego, sighted (24th) and videotaped (25th) an adult Cortez angelfish. The depth of the sightings was ca. 14 m and the size of the angelfish was estimated at 250 mm TL. The artificial reef, known as "Lost-and-Found Reef" and "Silver Strand Reef" is located ca. 2 nautical miles northwest of Imperial Beach.

These records demonstrate that the Cortez angelfish can, under certain oceanographic conditions, occur off our coast. This now permits us to add the species as well as the family (Pomacanthidae) to California's list of fishes (Hubbs, Follett, and Dempster 1979). Of significance are the dates surrounding the three records (1984 and 86), during and immediately following the most recent El Niño event off our coast. Coincidental to the California records, Lea observed juvenile Cortez angelfish at Islas San Benito, off Baja California (lat 28°13'N), in August 1984 and 1985.

Historically, tropical species have been recorded from California during anomalously warm oceanographic periods (Hubbs 1948, Radovich 1961). Fishes such as the Pacific seahorse, *Hippocampus ingens* (Jones, Dutton, and Snodgrass 1988); stone scorpionfish, *Scorpaena mystes* (Swift 1986); broomtail grouper, *Myctroperca xenarcha*; Gulf grouper, *Mycteroperca jordani*, Pacific spadefish, *Chaetodipterus zonatus*; threebanded butterflyfish, *Chaetodon humeralis*; blue-bronze chub, *Kyphosus analogous* (Brooks 1987); black triggerfish, *Melichthys niger*; redtail triggerfish, *Xanthichthys mento*; Pacific burrfish, *Chilomycterus affinis*; spotted porcupinefish, *Diodon hystrix*; and spiny boxfish, *Lactoria diaphana* are examples of eastern tropical Pacific or Indo-West-Pacific fishes known from a single or only a few records for California. The occurrence of the Cortez angelfish off our coast is an additional example of this type of expatriation.

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XANTHIC, GIGANTIC, CHINA ROCKFISH

On 18 May 1988 approximately two miles southeast of Crescent City, California (lat 41°42′ N, long 124°10′ W) commercial hook-and-line fisherman Ernie Gentry of the LADY MAE, fishing in 14 fathoms of water with a non-baited barbless hook, caught a 453 mm total length China rockfish, *Sebastes nebulosus*. The fish was shipped to F. Alioto Fish Company in San Francisco and the general manager, Joseph Cincotta, called the author to have the fish identified. This specimen is the largest China rockfish yet captured (Miller and Lea 1972) and the first known to exhibit xanthism.

Xanthism is the property of the skin to be marked by a predominance of yellow pigment. Xanthic fish have been reported on the West Coast for the following species: Dover sole, *Microstomus pacificus* (McCormick and Baldwin 1952); sablefish, *Anoplopoma fimbria* (Phillips 1952); and bocaccio, *Sebastes paucispinis* (Davenport 1966).

Normally China rockfish are a mottled brown or blue-black mixed with yellow and have a yellow stripe running from the anterior spines (between spines III and IV) of the dorsal fin down to the lateral line and thence along the lateral line to the caudal peduncle (Ayres 1854, Miller and Lea 1972). This specimen was a bright golden yellow with a few tiny black spots on the head

and several small patches of black on the dorsal fin membrane between the second and seventh dorsal spines (Figure 1)

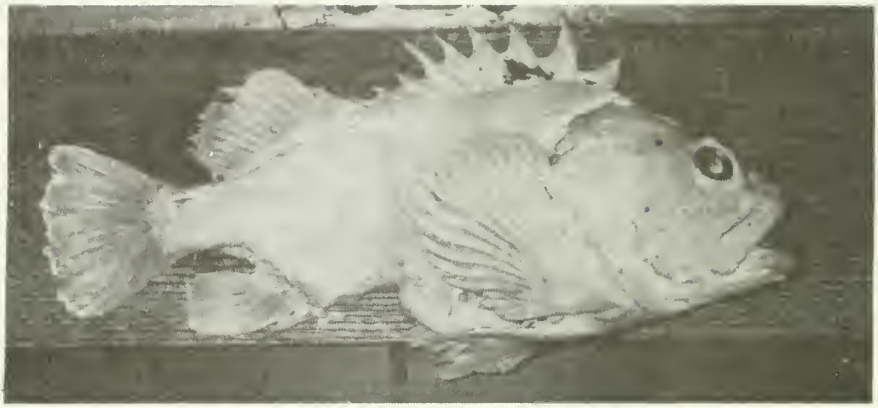

FIGURE 1. Xanthic, gigantic, China rockfish caught off Crescent City, California.

All the China rockfish's physical attributes correspond to those described for this species (Ayres 1854, Phillips 1952, Miller and Lea 1972). The total length of 453 mm exceeds the previously reported total length of 432 mm by five percent. This specimen had seven anal fin rays, 10 unbranched and 18 total pectoral fin rays, 13 dorsal fin rays, and 29 gill rakers (8 + 21 = 29). The following measurements were taken: standard length (367 mm), head length (148.6 mm), orbit width (32.2 mm), bony interorbital width (19.8 mm), suborbital height (14.1 mm) and pectoral length (109.7 mm).

The age of this fish was determined by four scientists experienced in aging rockfish using the experimental broken and burnt otolith method (Chilton and Beamish 1982). All scientists agreed that the fish was approximately 70 years old (ca. 1918 year class).

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RANGE EXTENSION AND COMMERCIAL CAPTURE OF THE NORTHERN ANCHOVY, *ENGRAULIS MORDAX* GIRARD, IN THE GULF OF CALIFORNIA, MEXICO

The distribution of the northern anchovy, *Engraulis mordax,* has for years been accepted as from the Queen Charlotte Islands, British Columbia to Cape San Lucas, Baja California, Mexico (Hildebrand 1943, Miller and Lea 1972, Hart 1973, Anonymous 1976, Ruiz-Dura 1985, Whitehead, et al. 1988).

There have been several previous reports of the northern anchovy in the Gulf of California, but all were unsupported by specimens, or were based on misidentifications. Wales (1932) reported a single small specimen (CAS 39907) caught in La Paz Bay, on 9 April 1931, but this small anchovy has been recently re-identified as *Anchoa* sp. (Richard Rosenblatt, Scripps Institution of Oceanography, pers. comm.). Data reports of California Department of Fish and Game Sea Survey Cruises aboard the ALASKA in the Gulf of California in 1961 (Cruise 61A5) and 1962 (Cruise 62A1) record the capture of 3020 northern anchovy (Heimann 1967, 1969). On 1 August 1961, 300 and 200 anchovy measuring 51-71 mm standard length (SL) were recorded from Santa Ana Bay south of Santa Rosalia, Baja California Sur (lat 26°58'N, long 112°01'W and lat 26°54'N, long 111°57'W respectively). On 26 February 1962, 20 anchovy larvae (not measured) were registered off Mazatlan (lat 23°12'N, long 106°26'W) and on 2 March 1962, 2500 (54–100 mm SL) anchovy were reported off the southern coast of Sonora (lat 26°40'N, long 109°40'W). Unfortunately, none of these specimens were saved and their identity must remain questionable. At 100 mm SL, there should be no difficulty to distinguish *Engraulis mordax* from similar round-bodied species of *Anchoa* (e.g. *A. ischana* or *A. helleri*). However, the existence of other anchovy species and genera may not have been realized. The catalogue of the Los Angeles County Museum of Natural History (LACM 36551-10) records the capture of 16 specimens (22–28 mm SL) of northern anchovy from Sea Survey cruise 922 on the R/V VELERO IV, 24 November 1967 in the southern Gulf of California (lat 25°20'N, long 109°59'W) (Robert Lavenberg, Los Angeles County Museum, pers. comm.). These specimens have been recently examined and were found not to be *Engraulis* (Geoff Moser, National Marine Fisheries Service, pers. comm.). We know of no other reports of northern anchovy in the Gulf of California.

In April and July 1986, a total of 37 northern anchovy adults were examined from commercial landings at the port of Guaymas, Mexico. Although the Guaymas fishing effort is normally directed toward sardine, anchovy were reportedly captured throughout the period of 5 March to 6 July 1986. Forty-eight landings totaling 2,071 metric tons from 13 vessels were said by vessel captains and port officials to be 100 percent northern anchovy. However, identification was confirmed only for the three catches recorded here.

On 12 April 1986, 11 specimens of northern anchovy were examined from a 10.8 metric ton landing of northern anchovy caught off San Carlos Bay, Sonora (lat 28°00'N, long 111°05'W) by the PISCIS. These fish have been deposited in the Marine Vertebrates Collection, Scripps Institute of Oceanography, La Jolla, California, as SIO 87–11 (103.5–117.2 mm SL). On 3 July 1986, 16 specimens (SIO 87–12, 106.7–120.5 mm SL) were examined from anchovies gilled in a

sardine net from a landing caught at San Rafael Bay (lat 28°30′N, long 113°00′W) off the coast of Baja California. Although specimens were not saved, 10 more northern anchovy were examined (106–120 mm SL) from a 1.0 metric ton landing of northern anchovy caught on 4 April 1986 at Tobari, Sonora (27°15′N, 110°30′W) by the PESCADOR VI. The geographic location of the three captures recorded here and those reported in the data reports of California Department of Fish and Game Sea Survey Cruises 61A5 and 62A1 are shown in Figure 1. Finally, 12 juvenile *Engraulis mordax,* 42–55 mm SL, were examined from a plankton haul in Bacochibampo Bay, near Guaymas, made on 16 April 1985. These fish are preserved as ITESM 85-2 in the fish collection of the Instituto Technològico y de Estudios Superiores de Monterrey, in Guaymas, Sonora.

Identification of these Guaymas specimens of northern anchovy was initially made using Hildebrand (1943), but was confirmed from the latest review of anchovies (Whitehead et al. 1988); specimens were also examined by Peter Whitehead. The standard length of our specimens (N=27) ranges from 103.5–120.5 mm. Other data are: branchiostegal membranes not united; anal fin origin under or posterior dorsal fin origin; head length (HL) 3.1–3.4 into SL; depth 4.8–5.8 into SL; pectoral axillary scale 0.63–0.94 into pectoral fin length; maxillary 1.2–1.3 into HL and is pointed posteriorly; mandible 4.6–5.2 into SL; dorsal rays 15–16; anal rays 20–21; pectoral rays 15–17; gillrakers 38–43 + 39–46.

Of anchovy genera in the northern part of the eastern Pacific, *Centengraulis* has broadly united branchiostegal membranes, while *Anchovia* has at least 50 lower gillrakers at only 40 mm SL (maximum 46 in adult *Engraulis mordax*). Only two other anchovy genera occur in this area, *Anchoa* and possibly *Anchoviella.* In neither of these do the lower gillrakers exceed 32 *(Anchoa delicatissima* and *A. nanus* to 28); whereas even at only 50 mm SL, there are already 35 lower gillrakers in *Engraulis mordax.*

These records constitute a substantial verified range extension for the northern anchovy, *Engraulis mordax.* Although the identification of northern anchovy from the California Fish and Game Sea Survey Cruises in the Gulf of California during 1961 and 1962 is uncertain, our recent confirmation suggests the possibility that the reports may be correct. Nevertheless, although an intensive Mexican fishery for sardine in the Gulf of California has been operating since 1971 (Arvizu-Martinez 1987), the capture of commercial volumes of northern anchovy has not been previously reported. The occurrence of northern anchovy in the Gulf of California, therefore, may represent an isolated, fourth sub-population, or an extension of the southern sub-population of the species (Vrooman, Paloma and Zweifel 1981).

The overall average standard length for the 27 adult specimens recorded here (112.9 ± 3.9 mm SL) is much larger than that reported for the southern sub-population of northern anchovy. Parrish, Mallicoate and Mais (1985) suggested that regional size differences in northern anchovy are due to differences in their growth rate and that fish of the southern stock reach an asymptotic mean size of 92 mm SL in about two years; central stock fish were found to grow throughout their lives and not reach anasymptotic size. They also suggested that regional variation in temperature may explain this variation in asymptotic size. If northern anchovy were isolated in cold deep waters in the Gulf of California, they could grow larger than southern subpopulation fish.

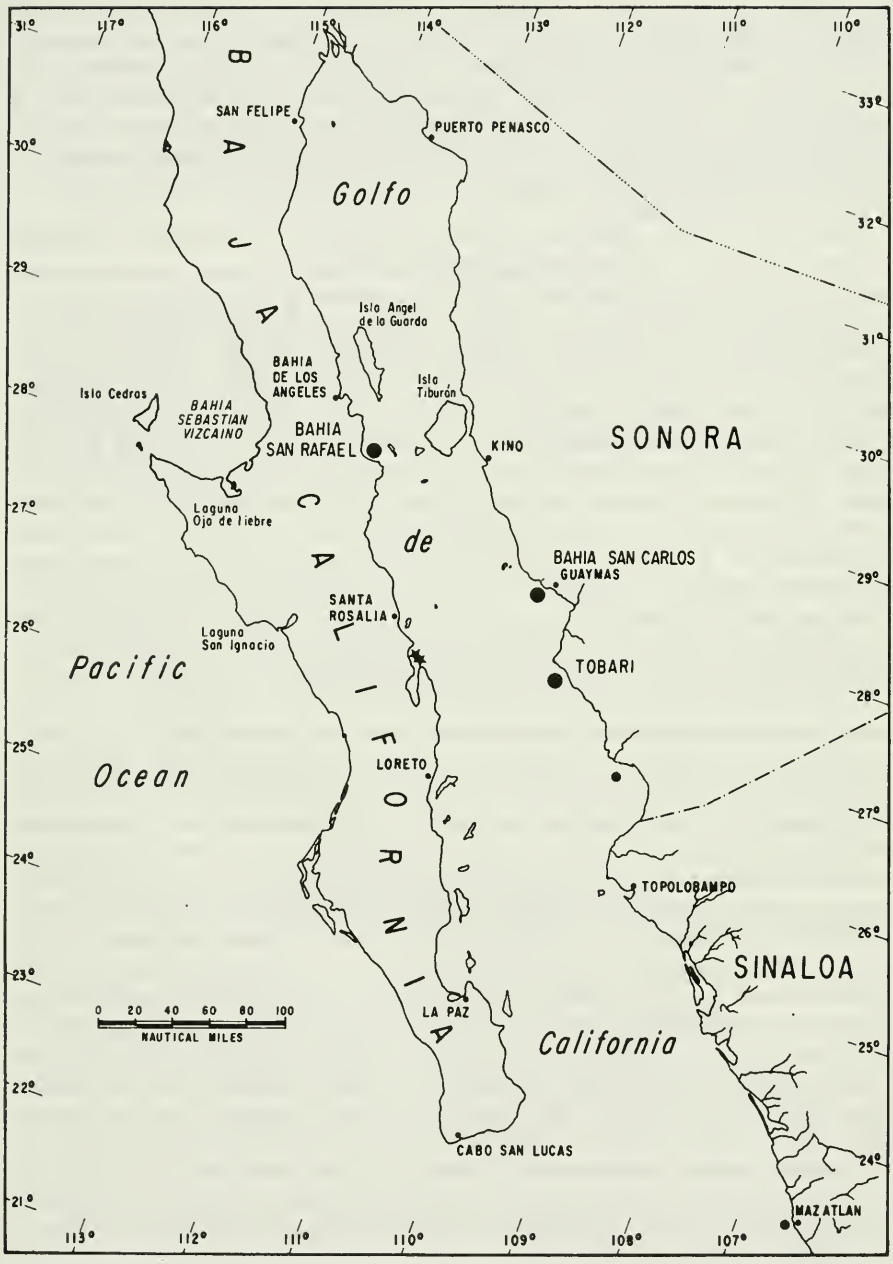

FIGURE 1. Capture sites for the northern anchovy collected in the Gulf of California, Mexico. (● = this study, ★ = Heimann 1967, • = Heimann 1969).

Nevertheless, the larger mean size of those reported here compared with those reported for the southern sub-population (113 *vs.* 92 mm SL), is most likely due to the nets used for sardine selecting for the largest available individuals of anchovy. Nets typically used by the Gulf of California sardine fleet have a stretched mesh of 19 and 25 mm, while the mesh opening for the typical anchovy net used in Mexico is 12 or 14 mm. Clearly, large random samples are needed to determine the size structure of the population of northern anchovy in the Gulf of California.

During anti-El Niño years, the southward California current turns westward off-shore typically at Magdalena Bay. At times, however, its cool waters extend farther south thus permitting the southern movement of temperate species that are normally limited at Cape San Lucas; under extreme conditions, California Current waters may even enter the Gulf of California (Roden 1958, Robles and Marinone 1987). During April–September 1986, the average surface temperature at Guaymas, Sonora, was colder than the long-term 1952–1985 monthly average (Cisneros-Mata unpub. data). Although the observed surface temperatures (22–28°C) were relatively warm for northern anchovy, the temperature below the seasonal thermocline might have been cooler and could have been fished by purse seines employed in the Gulf of California sardine fishery since they extend to a depth of about 64 meters. Negative surface temperature anomalies during April–September 1986 (up to −4.2°C in July), calculated from a 33-year mean (Cisneros-Mata unpub. data), were greater in 1986 than any reported during the previous five years suggesting a southern progression of isotherms that may have allowed southern sub-population northern anchovy to pass Cape San Lucas and enter the Gulf of California.

The presence of juvenile northern anchovy in Bacochibampo Bay near Guaymas in April 1985, nevertheless, shows that adults must have entered the gulf at least by the beginning of that year, if not during the end of 1984; cool water was also found during this period. Although negative temperature anomalies at Guaymas during January and February of 1985 (−0.75 and −2.25°C, respectively) would appear to be too late for the parents of these juveniles to have entered the gulf to spawn, cool isotherms must have passed Cape San Lucas about two months earlier allowing the adults to enter the gulf and spawn in subsurface waters. Furthermore, it is highly unlikely that the juveniles were caught in the spawning area of their parents. Near-surface advection to the Guaymas basin of California Current waters, as described by Robles and Marinone (1987), could also have transported eggs and larvae from a more southerly spawning site. Negative anomalies in sea-level and sea-surface temperature also occurred in 1961 and 1962 (Huato-Soberanis and Lluch-Belda 1987) when northern anchovy were reported by the California Fish and Game Sea Survey Cruises (Heimann 1967, 1969). Thus, northern anchovy appear to have entered the Gulf of California during periods when water temperatures were at least 2°C lower than normal. This often occurs during the recovery period after a strong El Niño event.

Although the 2071 metric ton total landing of northern anchovy in the Gulf of California is outstanding, it does not reflect the actual biomass. Reported availability was much higher, but vessel captains preferred to capture sardine

due to their higher off-landing value. Furthermore, because most vessels in the sardine fleet operate with a larger mesh sardine net, most captains try to avoid gilled anchovy. Due to the potential of predation by northern anchovy upon early life-history stages of sardine in the Gulf of California, as suggested by Butler (1987) for the Pacific coast population, it is important to determine the spatio-temporal distribution of northern anchovy, if and when they spawn in the Gulf, and their biomass. Furthermore, a northern anchovy fishery in the Gulf of California may offset periods of low sardine landings.

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A NORTHERN RANGE EXTENSION FOR THE THORNBACK, *PLATYRHINOIDIS TRISERIATA*

The thornback, *Platyrhinoidis triseriata,* is listed as having a range extending from Thurloe Head, Baja California, Mexico, to San Francisco, California and is considered rare north of Point Conception, California (Roedel 1953; Miller and Lea 1972; Eschmeyer, Herald and Hammann 1983). The southernmost specimen is deposited at the Natural History Museum of Los Angeles County.

On 3 May 1988, Antoine Venghiatis caught a thornback while fishing from shore with hook-and-line in Tomales Bay, approximately one nautical mile northwest of Inverness, California. Fishing depth did not exceed 3 m. The entrance to Tomales Bay is 32 naut. mi. (59 km) NW of San Francisco Bay.

The fish was 67 cm total length (TL) and had a disc width of 34 cm. The internal organs and pelvic fins had been removed shortly after capture, thus the sex of the fish was not determined. This specimen is catalogued at the California Academy of Sciences (CAS 63193) and represents a northern extension for the species.

On 7 June 1988 a second thornback was taken and released from a gill net operated by Frank Spenger in ca. 6 m of water opposite Heart's Desire Beach, Tomales Bay (3 naut. mi. NW of Inverness). The fish was identified and estimated at 40 cm TL by Jordan Gold, a California Department of Fish and Game observer (T. Moore, pers. comm.).

Of additional interest was the capture of a total of 20 thornbacks between 22–26 April 1988 by the commercial trawlers ROMANCE and PACIFIC SUN during three separate tows of a pair trawl near Pacifica, California, (just south of San Francisco). These fish had an average disc width of 45.8 cm, with a range of 27.9 to 56.0 cm. (D. Thomas, pers. comm.).

The above information indicates that the thornback may not be as rare north of Point Conception as previously thought.

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NORTHERN OCCURRENCE OF TWO ESTUARINE CRABS: THE FIDDLER CRAB, *UCA CRENULATA,* AND THE BURROWING CRAB, *MALACOPLAX CALIFORNIENSIS*

A male fiddler crab, *Uca crenulata,* was found in Goleta Slough, approximately 2 km E of the University of California, Santa Barbara campus (lat 34° 25'N, long 119° 50'W) (Figure 1), on 17 July 1986. The fiddler crab (16.5 mm carapace width (CW)) was found in the upper intertidal zone of the small estuary, in a muddy area vegetated with pickleweed, *Salicornia* sp.

Fiddler crabs typically occur on intertidal shores in protected locations in tropical, sub-tropical and warm temperate locations. *U. crenulata* is the only species of fiddler crab reported from California (Crane 1975). *U. crenulata* has previously been reported as far north as Playa del Rey, Los Angeles County (lat 33° 58' N, long 118° 27' W) (Garth and Abbott 1980). Johnson and Snook (1927) reported a male *U. crenulata* specimen measuring 19.7 mm CW and Allen (1980) reported males approaching 30 mm CW.

One male burrowing crab, *Malacoplax californiensis,* was collected on the Morro Bay mud flat during an early morning minus tide, several hundred meters S of the Morro Bay State Park (lat 35° 20' N, long 120° 50' W) (Figure 1) on 20 July 1986. The crab was collected in shallow water (ca. 0.5 m below MLLW) in a muddy area with patches of eelgrass, *Zostera* sp., and ghost shrimp, *Callianassa californiensis,* burrows. This specimen measured 31.3 mm CW.

M. californiensis is an intertidal to subtidal inhabitant of bays and protected waters in southern California and Baja California (Garth and Abbott 1980). *M. californiensis* was previously reported as far north as Mugu Lagoon, Ventura County (lat 34° 06' N, long 119° 05' W) (MacGinitie and MacGinitie 1969).

The northern extensions of these species may be the result of larval transport and recruitment associated with nearshore currents during the El Niño events of 1982 and 1983. The distances between the previously reported northernmost occurrences and those reported here are about 130 km for *U. crenulata* and 230 km for *M. californiensis.* Durations of the planktonic larval stages of *U. crenulata* and *M. californiensis* are unknown, but the span of planktonic life for several *Uca* species ranges from 17 to 28 d (Rabalais and Gore 1985).

The estimated velocity of northward nearshore currents in February and March of 1983 was 0.72 km/hr in the region of Point Conception (Figure 1) (Lynn 1983). Simpson (1984) reported the development of an anomalously strong inshore California Countercurrent which appeared earlier in the season (June–July) than in normal years (late summer) in association with the 1982–83 El Niño event. At an average ocean current velocity of 0.72 km/hr the transport of planktonic larvae from established colonies of either species could have occurred in less than 14 d. Northern range extensions of other southern invertebrate species have been reported during the 82–83 El Niño episode: the pelagic red crab, *Pleuroncodes planipes* (McGowan 1984), the euphausiid, *Nyctiphanes simplex* (Brodeur 1986), and the acorn barnacle, *Megabalanus coccopoma* (Newman and McConnaughey 1987).

We would like to acknowledge the students of the University of California, Santa Barbara, Biology 141 class of 1986, who brought many interesting things to light on early morning field trips to muddy places, and A. M. Wenner and H. M. Page for their comments on the manuscript.

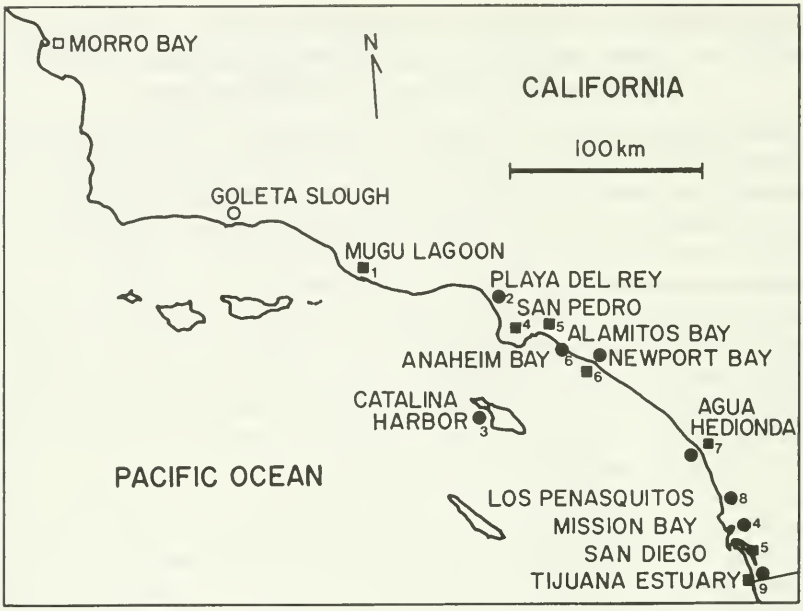

FIGURE 1. Occurrence of the fiddler crab, *Uca crenulata* (●), and the burrowing crab, *Malacoplax californiensis* (■), in southern and central California. Open symbols indicate our new observations for each species. References for each record are indicated by number as follows: 1) MacGinitie and MacGinitie 1969, 2) Garth and Abbott 1980, 3) personal observation 1985, 4) Johnson and Snook 1927, 5) Rathbun 1918, 6) Ricketts *et al.* 1985, 7) Bradshaw *et al.* 1976, 8) Gross 1961, 9) Zedler and Nordby 1986.

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OBSERVATIONS ON SALT CREEK PUPFISH MORTALITY DURING A FLASH FLOOD

Salt Creek is a small stream in southeastern California that originates at McClean Spring in Death Valley National Monument. The stream is characterized by large fluctuations in temperature, salinity, and flow. During winter, Salt Creek may extend 5 or 6 km downstream of the headspring. During the hot summer, reduced spring flow and high evaporation rates restrict surface water to 1 or 2 km downstream of the spring. Reduced flows and hypersaline conditions of remaining pools result in substantial mortality of Salt Creek pupfish, *Cyprinodon s. salinus,* during the summer (Miller 1943, Stuenkel and Hillyard 1981). No reports of pupfish mortality during high water conditions exist.

During 15–18 April 1988, we observed mortality of Salt Creek pupfish because of a flash flood. Although average annual rainfall at the town of Furnace Creek (18 km SE of Salt Creek) is only 5.16 cm, rainfall amounts at Furnace Creek were 3.73 cm, 0.51 cm, and a trace on 15, 16, and 17 April, respectively. On the same dates, rainfall at Scotty's Castle (57 km NW of Salt Creek) measured 4.45 cm, 0.76 cm, and 0.15 cm. Rains were so severe on 15 April that State Highway 190 was closed between Stovepipe Wells and Furnace Creek in numerous places. Salt Creek flows extended many km below their usual terminus during 15–18 April.

As the initial flood flows receded in the afternoon of 15 April, we collected 12 dead Salt Creek pupfish by hand from desiccating pools along the margin of the creek near the interpretive natural history display and boardwalk. These specimens are now housed at the California Academy of Sciences (CAS 63183). We returned on 18 April when flows were greatly reduced but still substantially above normal. On that date, three people searched downstream of the boardwalk (below the extent of normal flow for that time of year) for dead pupfish and a second group of three people searched the Creek near the boardwalk. An additional 64 dead pupfish were found in two hours of searching. The downstream party found only four pupfish (range 12–30 mm total length (TL), $\bar{x} = 21.5$), whereas 60 pupfish (range 23–45 mm TL, $\bar{x} = 35.9$) were found along 395 m of the Creek next to the boardwalk. These fish were then measured to the nearest mm total length (TL) and returned to the location in which they were found. Our observations include only a small portion of pupfish killed during the flood. By 18 April, many scavengers (especially birds) were feeding on the dead pupfish. Tracks could be traced from dry pool to dry pool as one coyote fed on dead pupfish. Many additional live pupfish were observed on 18 April isolated in pools that would soon dry.

Numerous surviving pupfish also were observed in the main flow of Salt Creek. From 15–18 April, a total of 76 stranded pupfish was found (Figure 1). Average total length of the 76 fish was 35.2 mm. For the subspecies, the range in adult size is approximately 30–49 mm TL (Miller 1943).

Based on our sample, most adult pupfish that were killed died as a result of seeking refuge laterally as the creek waters rose. When the waters receded, many of these fish were trapped in drying pools isolated from the main flow. In contrast, juvenile pupfish were killed after being displaced downstream to areas of the Creek lacking permanent water. Water erosion created a 12 cm vertical drop in one section of the Creek that would prevent fish displaced downstream from returning to areas of permanent flow. The difficulty in observing smaller fish renders impractical a quantitative comparison of juveniles versus adults killed. It is significant, however, that no small dead fish (< 23 mm TL) were found in the area of permanent flow and no large adults were found in the downstream area of intermittent flow.

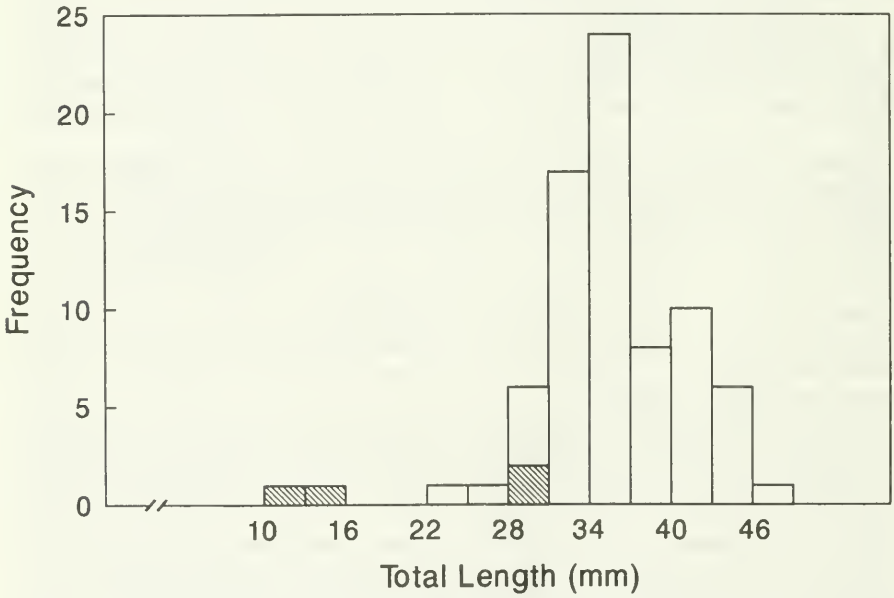

FIGURE 1. Length frequency of 76 Salt Creek pupfish, *Cyprinodon s. salinus,* killed during 15–18 April 1988 flash flooding. Crosshatching represents those individuals collected downstream of usual surface flow.

In other southwestern streams, flash floods are known to wash large numbers of immature fishes into downstream areas where they are lost to populations (John 1963, 1964). Fish smaller than 10 mm TL appear to be extremely susceptible to downstream displacement (Harvey 1987). The inability of young fish to maintain their position during floods probably is a function of their reduced swimming endurance when compared to longer conspecifics (Beamish 1978, Boyar 1961).

Since the original description of this species by Miller (1943), most studies have been restricted to physiological aspects of its life in extreme environments (e.g., Stuenkel and Hillyard 1981). No studies of population sizes have been made. Floods, droughts and resultant extremes in water characteristics are natural features in the life history of this fish. But until population estimates are made, quantifying effects of environmental stochasticity on population sizes will remain difficult.

ACKNOWLEDGMENTS

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BOOK REVIEWS

CALIFORNIA MAMMALS

by E. W. Jameson, Jr. and Hans J. Peeters 1988. University of California Press, Berkeley, CA, 403 p., illustrated. $24.95

An advertisement in the November, 1987 issue of the *Journal of Mammalogy* stated that this book "offers for the first time a guide to California's own fauna", and includes descriptions, drawings, color photographs, maps, keys for identification, and an introduction to the study of mammals. This leads one to expect something more than, and different from, Lloyd Ingles' 1954 book on *Mammals of California and Its Coastal Waters* (later *Mammals of the Pacific States*).

Instead, *California Mammals* has been prepared for 'travellers, campers, hikers, sportsmen, nature lovers, and outdoorsmen', rather than being directed toward wildlife professionals or mammalogists. It is Number 52 in the California Natural History Guides, a series which has been issued for the interested public by the UC Press since 1960.

The first 88 pages deal with general topics, such as mammalian reproduction, dormancy, senses, migration, and food. This section is followed by 252 pages of species accounts, forming the bulk of the book. Each species account includes notes on the animal's appearance, distribution, food habits, and reproduction. Often additional information is provided, which helps to further characterize the species, or adds some pertinent bit of information. Keys are included to help with the identification of some groups which contain several similar species, such as chipmunks and kangaroo rats. Black and white sketches of some of the species, or of their skulls, are scattered through this section, which also contains the 16 colored plates (not photographs). All illustrations are by Peeters (some are quite good), and the text refers to them by number. Range maps (43 pages) are not referred to in the species accounts. A brief glossary (7 pages) and a nine page index complete the book.

Disappointing aspects of the book include the many unfortunate errors or other problems. The vast majority of these could easily have been eliminated or corrected in manuscript. During a single rapid scan of the book a four page list of such problems was developed, but a few examples will be enough to make the point:

> On the map showing the counties of California, San Luis Obispo is misspelled. 'Body length' and 'basal length' are terms used in some keys or species accounts, but are nowhere defined. The term 'pinna' is in the glossary, but 'ear flap' is used in the text. Bottle-nosed dolphins do not "occur all along our coast", but are limited to warmer waters south of Point Conception. The fact that some caterpillars defoliate pine trees is not relevant to a discussion of red tree voles. Elk are not unique among North American deer in having upper canine teeth, since caribou usually have them also. House mice are not similar in size to harvest mice, as the measurements given for these two species clearly indicate. The temporal ridges of the gray fox are not the sagittal crest. The lower jaw of a deer does not articulate with the skull as shown on page 216. Muskrats are not an introduced species to the state, although the central valley population was introduced there.

A list of endangered species and subspecies is provided (dated 1980), but subspecies are never mentioned or defined in the text. Information about the fur industry in California is presented, but the figures date from 1978–1979. Similarly, the discussion of the fur seal treaty involving the United States, Canada, Russia, and Japan is out of date. Feral donkeys, horses, and pigs are included in the species accounts, but not feral cats, sheep, or goats. Feral dogs are discussed, with the conclusion that they really are not feral. The introduced opossum, axis deer, and fallow deer are discussed in species accounts, but the introduced Barbary sheep, Himalayan tahr, and European rabbit are not. The 'Brown Rat' is not feral.

In a clearly introductory book such as this, it is unfortunate that Jameson chooses to emphasize a few common names which differ from those which have been accepted by most recent authors. 'Guano Bat' or 'Parasitic Mouse' are not really improvements over the more familiar Brazilian free-tailed bat and California mouse. Further, an editorial policy of capitalizing the first letter of proper names, but not that of general names, leads to awkward arrangements, such as: "observe a fox, Raccoon, or flying squirrel". In spite of this policy, *Peromyscus maniculatus* is a Deer Mouse in one place, but only a deer mouse in another.

The writing style occasionally develops such uncomfortable phrasing as "The origin of a migration is seldom the exact place of birth", or "pocket mice tend to forage under the cover of shrubs; kangaroo rats . . . move much greater distances when gathering food." It can also lead to

inaccuracies, including reference to the 'pawed ground' produced by a pronghorn, which has no paws, or the assertion that raccoons eat birds' nests.

Some of the range maps are incorrect (black bear, Heermann's kangaroo rat, beaver, porcupine), and others cannot be clearly interpreted (Townsend's pocket gopher, Roosevelt elk, pronghorn).

Basically, this publication adds little to what is already available in any of the standard field guides to mammals, most of which also offer color illustrations or photographs, species descriptions, and distribution maps. *California Mammals* does add black and white sketches of some mammals, or of their skulls, and provides keys to difficult groups. It lacks a complete check list of the species which occur in the state, and has fewer color illustrations than most field guides; there are no color photographs. The range maps are of California, rather than of the entire continent, and should therefore show more detail. The book will be helpful to novices, and the keys may be useful to professionals.

—Aryan I. Roest

FISHERY DEVELOPMENT EXPERIENCES

by W.H.L. Allsopp. 1985. Fishing News Books, Ltd., Farnham-Surrey, England, 160 p. 12.50 paperback.

W.H.L. Allsopp reviews eight fishery development projects carried out to improve fishery utilization in third world countries of southeast Asia, the middle east, Africa, and latin America. The projects, partially funded by the United Nations, other multi-national aid agencies, or individual country aid agencies, deal with improvements and modernization of artisanal fisheries, vessel and shore facility construction for offshore fisheries, training, fishery and aquacultural financing, upgrading research and development capability, and assistance to multi-national and inter-regional projects.

Projects are reviewed with considerations of the project background and objectives, inputs in funds and personnel, outputs in products or services, effects and impacts of the project, and evaluation and assessment. Host countries and exact locations are treated anonymously to allow critical review.

Various degrees of success were achieved in carrying out the projects. The tropical project locations presented problems in fish processing, preservation, and distribution. Host country commitment and availability of key personnel had effects as did the implementation of the 200 mile exclusive economic zone and the onset of the worldwide fuel crisis.

Dr. Allsopp evaluates each project critically and provides reasons for success or failure. Following each review, a list of selected references is provided. A final chapter on conclusions and recommendations contain perspectives on lessons learnt and factors that foster success in development project success.

The wide use of acronyms throughout the book is somewhat confusing but excusable due to lengthy agency and organization titles. Overall, the book was extremely interesting. The evaluation framework, conclusions and recommendations could be applied to domestic and foreign development projects alike. This book is recommended reading for administrators, planners, and personnel, of fishery development projects.

—Tom Jow

WILDLIFE IN AMERICA

by Peter Matthiessen. 1987. Viking (New York, NY). 332 p., cloth $29.95.

This volume is reputed to be a complete revision of the original 1959 edition. It "reproduces all the features of the original, with color plates, hundreds of line drawings, black-and-white photographs, and maps; new data are included throughout the text as well as in a new epilogue. Appendices contain information on all the species listed in the Environmental Protection Law as threatened, endangered, or newly extinct, a chronology of wildlife legislation, and an exhaustive bibliography".

Although this reviewer has not seen the original edition and did derive a goodly amount of interesting and valuable information from the new text, a book of this kind faces an inevitable and probably futile challenge: to remain topical given the rapid change of status in our wildlife resources, particularly those in extremis. The latter's fate, such as the California condor, can change rapidly. Even the epilogue of Matthiessen's newest effort fails to bring to date the sad sage of our largest North American vulture; there is no mention of the captive status of the entire existing population of this species. Similar situations exist for the red-cockaded woodpecker and even the

black-footed ferret, although the latter is the subject of prolonged discussion in the epilogue, but in a manner which immediately dates the material for the reader familiar with latest developments regarding the occurrence and distribution of this mustelid. In addition, for those concerned with taxonomic matters, the recent changes in systematic treatment of local birds (The A.O.U. Check-list of North American Birds, 1983) are not referenced in the new edition (examples include the retention of Ipswich and Savannah sparrows as separate species, and the New World wood warblers as a family rather than the new status as subfamily parulinae in the newly reconstructed Family Emberizidae). This gives reason to suspect that other animal classes with which this reviewer is not familiar may suffer the same defect.

The line drawings greatly enhance both the artistic merit of the book and assist in visualizing relatively obscure species. The color plates are well reproduced and one must especially commend the publisher for full use of page space; several recent publications offered at great price waste much potential space on excessively large margins. I noted no typos and simple errors were few (one example: on page 31, the 'yellow-billed tropic bird' presumably refers to the white-tailed tropicbird).

Given my critical remark about the constant state of siege and change for North American wildlife, it follows that the newest edition of a work reviewing the status of that subject is bound to be more current that its predecessor, and consequently of greater value to the reader. As long as that reader remains aware of such dynamic change, this volume is a source of general review and a starting point for further efforts to ascertain the current status of an endangered species.

—Bruce G. Elliott

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INSTRUCTIONS TO AUTHORS

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

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