CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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ERRATUM

Hanley, T.A. and J. L. Page. 1982. Differential effects of livestock use on habitat structure and rodent populations in Great Basin Communities. Calif. Fish Game, 68(3):160–174.

Page 162, Table 1. The following habitat types should be listed in the "Habitat types" column, rather than the "Association groups" column: bitterbrush-big Sage/bluebunch wheatgrass, juniper/big sage/bluebunch wheatgrass, big sage/Idaho fescue, big sage-snowberry/Idaho fescue.

IN MEMORIAM

JOHN E. FITCH

Fishery Science lost one of its finest talents by the death of John Edgar Fitch on 30 September 1982, after a lengthy battle against cancer. He leaves a legacy of scientific achievement equaled by very few in our profession. His work with fish otoliths in systematics, archeology, and paleontology is classic. He is survived by his wife, Arline, and his children, John, Richard, and Janis.

John Fitch was born in San Diego, California, on 27 June 1918. He earned his BA in zoology from San Diego State College in 1941, and his MA from the University of California at Los Angeles in 1963. He joined the, then, Division of Fish and Game in April 1941 as an Assistant Fish and Game Warden at Mt. Whitney Hatchery. Shortly thereafter he entered the Army as a Private. He was discharged 4 years later a Captain in the Signal Corps and returned to Mt. Whitney Hatchery. In June 1946, he was appointed Junior Aquatic Biologist at the California State Fisheries Laboratory, at Terminal Island, to work on mackerel. He rose rapidly through positions of increasing responsibility, and was appointed Laboratory Director in 1956. He held the position of Research Director at the time of his retirement from the Department in June of 1979.

He was editor of marine publications from 1952 to 1966 and from 1962 to 1966 he was Editor-in-Chief of *California Fish and Game.*

John earned a worldwide reputation for his accomplishments and brought credit to the Department. Although he listed his field as systematic ichthyology, his interests and abilities were diverse. He published over 100 papers based on his work on the comparative morphology of fish otoliths; fish biology, age composition, habits, habitats and systematics; fossil fishes of North America; and use of teleost fish otoliths in fishery biology, food habit studies, taxonomy, archaeology, and paleontology. He also found time to become the Department's leading authority on marine mollusks. In recognition of his achievements he was named a research associate by the Los Angeles County Museum of Natural History, Scripps Institution of Oceanography and the Santa Barbara Museum of Natural History. He was also adjunct Professor of Biology, Graduate School, University of Southern California. He was given the Membership Award of Excellence by the American Fisheries Society, California-Nevada Chapter in 1971 and in 1982 was honored by San Diego State University, College of Sciences, as its outstanding alumnus of the year.

John was a unique individual. He was an avid hunter, fisherman, and skin diver. To those who knew and worked with him, he could be a gruff and stern taskmaster and sometimes an impatient supervisor. At the same time he could be a gentle, thoughtful man. He was a gifted storyteller and a consummate teacher. His influence on and guidance of many young scientists did much to assure their success in their chosen field. He was truly an outstanding scientist and human being.

We shall miss John. The Department of Fish and Game and California fisheries are better because of his contributions. Those who follow will find his record of achievement a lofty goal, indeed, to attempt to reach. —*John L. Baxter.*

Calif. Fish and Game 69(1): 5–17 1983

SOFT BOTTOM INFAUNAL COMMUNITIES IN MISSION BAY [1]

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During 1970–1977 benthic grab samples were examined to determine the composition of the infauna of the soft bottom sediments in Mission Bay, San Diego. A total of 180 species and 22,119 specimens of marine invertebrates were collected. The polychaete, *Lumbrineris minima,* numerically dominated the fauna, and polychaetes as a taxon contributed the largest proportion of the number of individuals (65%) and the greatest biomass (43%). The species composition of the infaunal benthos of Mission Bay does not appear to be markedly different from that of other bays in southern California and northern Baja California.

INTRODUCTION

The present area of Mission Bay Park originally was composed of a series of salt marshes, tidal channels, and a shallow central bay. Between 1946 and 1962 major dredging within the bay and modification of the San Diego River Floodway brought the area to its present-day configuration. Few studies were made in Mission Bay during its natural condition prior to the establishment of the park. Fry and Croker (1934) presented a short list of the common fish and major invertebrates. Subsequent to the formation of the park, another generalized paper (Chapman 1963) again listed the more common fish and invertebrates. No quantitative benthic studies appear in the literature, although one quantitative phytoplanktonic study has been made (Fairbanks 1969). Although benthic studies are lacking in Mission Bay, surveys have been made of the benthic fauna in several other embayments in southern California and northern Baja California: San Diego Bay (Ford and Chambers 1973; Ford, Chambers, and Chambers 1975), San Quintin Bay (Barnard 1970), Newport Bay (Barnard and Reish 1959), Anaheim Bay (Reish, Kauwling, and Schreiber 1977; Reish 1977), and Los Angeles-Long Beach Harbor (Reish 1959). Certain areas of Mission Bay are subjected to yearly or biannual dredging, and the effect of dredging on the benthic fauna is not documented. Dredging has been shown to be the major factor influencing the sediment composition of San Diego Bay (Smith 1976).

During the past 7 years, benthic sampling has been conducted in Mission Bay in conjunction with classes in biological oceanography, an advanced senior-graduate level course at San Diego State University. Although the specific purpose of these studies has been to introduce students to the techniques of sampling benthic environments, the acquired data have contributed to a description of the infaunal benthos of Mission Bay State Park. The present information on species composition, distribution, abundance, and biomass of benthic marine invertebrates can serve as a baseline for future ecological studies within the park.

METHODS

Ten subtidal stations within Mission Bay Park (Figure 1) were chosen for

[1] Accepted for publication October 1981. Contribution No. 51 from The Center for Marine Studies, San Diego State University.

analysis of the infaunal benthos during the period 1970–1977. Areas represented by these stations include channels, protected basins, and open bay habitats. Each of these stations was sampled between five and seven times during the 7-year period. Sampling was conducted from a variety of small boats, one of which was equipped with a winch and davit for obtaining grab samples. At each station simultaneous biological and hydrographic measurements were taken. Surface and bottom temperatures ($\pm$0.1°C) were obtained with a thermister telethermometer and most dissolved oxygen ($\pm$0.2 mg/liter) samples were determined with a polarographic oxygen electrode analyzer. Some dissolved oxygen levels were determined by analysis of water samples using the Winkler titration method. Surface and bottom salinities ($\pm$0.1 ‰) were determined with an induction salinometer, and supplemented by measurements made with a hydrometer and by silver nitrate titration. Light intensities at representative depths were measured with a submarine photometer; water transparency was estimated with a standard Secchi disc.

At each station, replicate grabs were taken with a single-wire type 0.1m^2 Hayward orange peel grab bucket having an approximate nominal capacity of five liters. Sediment volumes of the samples were measured to the nearest 0.1 liter and found to vary from 1.3 to 7.01 liters. Most sediment volumes were within the range of 4 to 6 liters, depending on the type of bottom sediment and the presence of plant mats on the bottom. The mean sediment volume of 80 grab samples was 4.55 $\pm$ 0.18 liters. The grab penetrated approximately 15–20 cm into the sediment. Replicate grabs were taken within a 3 to 6-m radius of the station location.

The temperature of the sediment was taken from the grab sample immediately following collection. Small sediment cores were removed for analysis of grain size and organic content. The samples were washed through a 760 μm mesh sieve and all material retained by preservation in 5% buffered formalin, and later transferred to 70% ethanol. Animals were sorted to major taxonomic groups and blotted wet weight biomass determined to the nearest 0.1 g. The organisms were then identified to the lowest possible taxonomic category. Routine enumeration of organisms was done by students in biological oceanography classes under the supervision of D. M. Dexter and R. F. Ford. Identification of some species was made or confirmed by the following individuals: J. Carter, R. Darby, K. Fauchald, R. Given, S. Hosmer, J. Homziak, A. Muscat, and T. Winfield.

Species diversity was determined using the Shannon-Weaver diversity index (H′) for each station on each sampling date, and for the total stations, all samples pooled. Sorenson coefficients of community (Brower and Zar 1977) were calculated to compare within station and between station similarity. The coefficient of community, an expression of the degree of similarity between two or more samples, ranges from 0 for samples having no species in common, to 1.0 for samples indentical in both species composition and in quantitative values for the species. The degree of similarity for station pairs was calculated and arranged in a two axis system on the basis of differences in composition. The differences are expresed by community similarity coefficients (Beals 1973) and presented in a community ordination diagram.

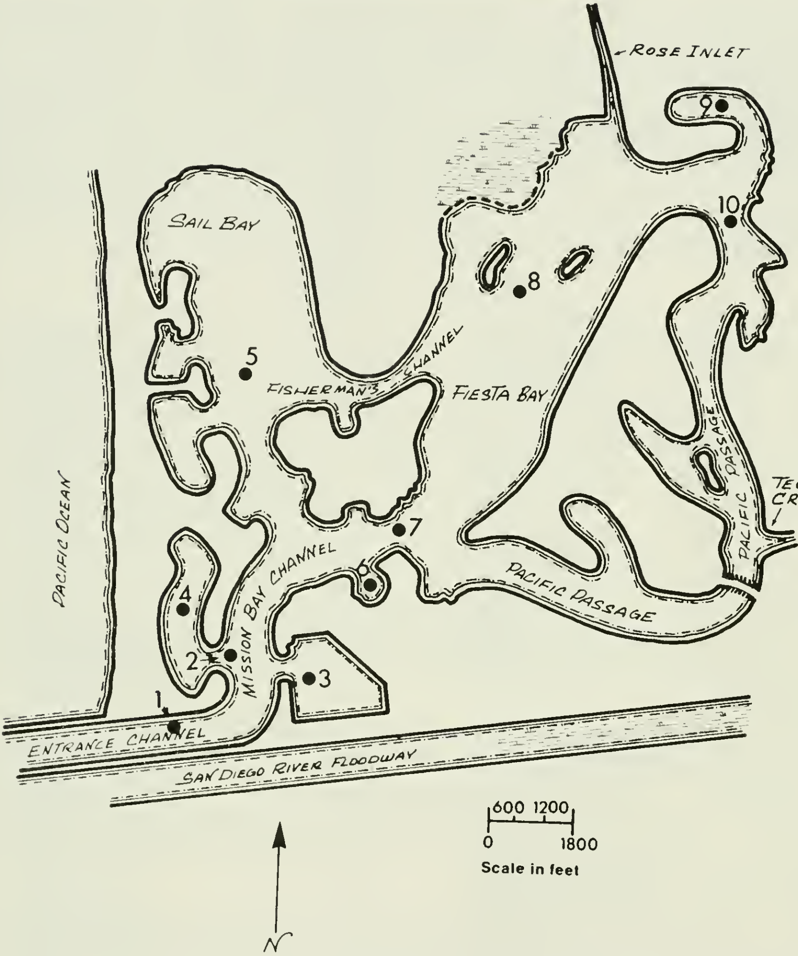

FIGURE 1. Location of benthic stations in survey of Mission Bay infauna during 1970–1977. Mission Bay Park contains 4,224 acres: land, 1,860; water, 2,228; marsh, 130.

RESULTS AND DISCUSSION

Physical Characteristics

Temperature fluctuates considerably within Mission Bay; lowest temperatures occur in late winter and highest temperatures in early fall. The range in bottom temperatures observed at the study site was 11.5 to 23.8°C, with the coolest temperatures occurring near the entrance to the bay and the highest temperatures occurring in the shallow waters of the inner bay. Normally, there is very little freshwater entering the bay; the major additions occur at Rose Inlet and Tecolote Creek (Figure 1) during the rainy season. As a result, the salinity does not vary markedly. The total range in salinity near the bottom observed during the course of the study was 30.4 to 34.6 ‰. Both salinity and temperature ranges within Mission Bay are more extensive than were measured during this study

(Fairbanks 1969). Dissolved oxygen concentrations varied with temperature and station location, but were generally 5 to 7 mg/l. Water transparency decreased with distance from the entrance to the bay.

A variety of sediment types occur in Mission Bay. Stations 1, 2, and 7 are areas with sufficient water movement so that a sand bottom is maintained. Median grain size at these stations was 236, 167, and 161 μm, respectively. At other stations within the bay, the sediment was high in silt and clay content and can be characterized as "mud." The organic content of the sediment ranged from 2.4 to 6.3%, with higher values occurring in protected embayments.

Faunal Characteristics

A total of 236 grabs (23.6 m^2 surface area) was taken, from which 22,119 individuals having a wet weight biomass of 778.63 g were isolated. One hundred-eighty species were collected in these samples (Table 1). Average density of the fauna was 973 individuals/m^2 of sediment surface area and average biomass was 33 g/m^2. The benthic fauna was dominated in terms of numbers of individuals by the polychaetes which contributed 65% of the total, followed by molluscs (15%), arthropods (11%), other groups (7%), and echinoderms (2%). Numerically, species dominance was shared approximately equally among molluscs (31%), polychaetes (28%), and arthropods (27%). In terms of biomass, the benthic infauna was dominated by polychaetes (43%) and molluscs (30%), with lesser proportions being contributed by echinoderms (12%), other groups (9%), and arthropods (6%). Echinoderms and arthropods were relatively more abundant at the sandy bottom stations (1, 2, 7) and were rare or absent from muddy sediments.

Of the 180 species collected from the benthos of Mission Bay, only 14 species contributed more than 1% to the faunal composition. These species included 10 polychaetes, 2 amphipods, a hemichordate, and a bivalve. The percent contribution, frequency of occurrence at stations, frequency of occurrence through time, probable feeding mechanisms, and geographical ranges of these 14 species were recorded (Table 2).

When the data from all stations within Mission Bay were combined, and the results compared between seasons and years, the polychaete *Lumbrineris minima* is found to be the numerical dominant of the fauna. Four of the five most numerous species are polychaetes with the fifth species being either an amphipod or a mollusc. The relative abundance, density, and presence in the samples of these species are variable through time and exhibit no correlation to the seasons.

Comparison of Stations

Station characteristics including the frequency of sampling, average bottom depth, mean density, mean biomass, diversity, and coefficients of community were synthesized (Table 3). Frequently occurring species at each station (those species collected in 60% or more of the samples) and the five most abundant species at each station (all samples pooled) were tabulated (Table 4).

Station 1, located in the entrance channel to Mission Bay, showed the greatest temporal fluctuation in faunal composition. There was only a 9.7% similarity between samples taken at Station 1, and a total similarity with all other stations of 13.3%. The community dominants reflected the instability in faunal composition. *Atylus tridens* and *Dendraster excentricus* dominated the fauna numerically in March 1970; *D. excentricus* was dominant in October 1970. Other dominants were *Nephtys caecoides* in March 1971, nematodes and *Olivella biplicata* in April 1972, *Paraphoxus epistomus* in September 1975, and *N. caecoides* and *Branchiostoma californiense* in September 1976. Station 1 had the lowest density and the lowest diversity of all the stations.

TABLE 1. Systematic List of Infaunal Organisms Collected from Stations 1 Through 10 During 1970–1977 in Mission Bay.

Cnidaria: Hydrozoa
- *Corymorpha palma*

Cnidaria: Anthozoa
- *Edwardsiella california*
- *Renilla kollikeri*
- *Stylatula elongata*
- *Zaolutus actius*

Platyhelminthes: 1 unidentified species
Nematoda: 1 unidentified species
Nemertea: several unidentified species
Brachiopoda:
- *Glottidia albida*

Sipunculida:
- *Golfingia hespera*
- *Siphonosoma ingens*

Echinodermata: Echinoidea
- *Dendraster excentricus*
- *Lytechninus anamesus*

Echinodermata: Holothuroidea
- *Leptosynapta albicans*
- *Molpadia arenicola*

Echinodermata: Ophiuroidea
- *Amphiodia occidentalis*
- *Amphiodia psana*
- *Amphiodia* sp.
- *Amphipolis squamata*
- *Ophionereis annulata*
- *Ophiothrix spiculata*

Hemichordata: *Saccoglossus* sp.
Chordata: Urochordata
- *Styela barnharti*
- *Styela montereyensis*

Chordata: Cephalachordata
- *Branchiostoma californiense*

Chordata: Vertebrata, Pisces
- *Clevelandia ios*
- Gobiidae—unidentified juveniles
- *Porichthys myriaster*

Mollusca: Gastrpoda
- *Acteocina culcitella*
- *Acteocina inculta*
- *Acteon punctocoelotus*
- *Anachis penicillata*
- *Aplysia californica*
- *Balcis micans*
- *Bulla gouldiana*
- *Caecum californicum*
- *Cerithidea californica*
- *Conus californica*
- *Crepidula onyx*
- *Epitonium tinctum*
- *Homalopoma paucicostatum*
- *Marginella californica*
- *Mitrella carinata*
- *Mitrella* sp.
- *Nassarius perpinguis*
- *Ocenebra poulsoni*
- *Odostomia resina*
- *Olivella biplicata*
- *Ophiodermella ophioderma*
- *Rissoina bakeri*
- *Sinum* sp.
- *Terebra danai*

Mollusca: Scaphopoda
- *Dentalium neohexagonum*

Mollusca: Bivalvia
- *Argopecten aequisulcatus*
- *Chione californiensis*
- *Chione fluctifraga*
- *Chione undatella*
- *Cooperella subdiaphana*
- *Corbula luteola*
- *Cryptomya californica*
- *Cuspidaria apodema*
- *Donax gouldii*
- *Entodesma pictum*
- *Laevicardium substriatum*
- *Lucina (lucinisca) nuttalli*
- *Lyonsia californica*
- *Macoma identata*
- *Macoma secta*
- *Mactra californica*
- *Musculus senhousei*
- *Parvilucina tenuisculpta*
- *Periploma discus*
- *Protothaca laciniata*
- *Protothaca staminea*
- *Saxidomus nuttalli*
- *Solen rosaceus*
- *Spisula hemiphilli*
- *Tagelus californianus*
- *Tellina bodegensis*

TABLE 1. Systematic List of Infaunal Organisms Collected from Stations 1 Through 10 During 1970–1977 in Mission Bay.—Continued

- Tellina carpenteri
- Tellina idae
- Tellina modesta
- Thyasira sp.

Pycnogonida: unidentified species

Crustacea: Ostracoda
- 2 unidentified species

Crustacea: Cumacea
- *Campylaspis rubromaculata*
- *Cumella* sp.
- *Oxyurostylis pacifica*

Crustacea: Tanaidacea
- *Leptochelia* sp.

Crustacea: Isopoda
- *Excirolana chiltoni*
- *Exosphaeroma* sp.
- *Idarcturus allelomorphus*
- *Idothea urotoma*
- *Serolis carinata*

Crustacea: Amphipoda
- *Atylus tridens*
- *Aoroides columbiae*
- *Ampelisca cristata*
- *Amphithoe* sp.
- *Caprella* sp.
- *Corophium* sp.
- *Elasmopus* sp.
- *Eohaustorius sencillus*
- *Eohaustorius washingtonianus*
- *Hyale frequens*
- *Listriella eriopisa*
- Lysianassidae—unidentified
- *Mandibulophoxus gilesi*
- *Megaluropus* sp.
- *Monoculodes zernovi*
- *Paraphoxus epistomus*
- *Paraphoxus* sp.
- *Photis brevipes*
- *Photis* sp.
- *Pleustes platypa*
- *Podocerus cristatus*
- *Pontogenia prostrata*
- *Synchelidium shoemakeri*

Crustacea: Natantia
- *Alpheus dentipes*
- *Crangon stylirostris*
- *Hippolyte californiensis*

Crustacea: Reptantia
- *Callianassa californiensis*
- *Hemigrapsus oregonensis*
- *Lepidopa myops*
- *Lophopanopeus diegensis*
- *Pinnixa farba*
- *Pinnixa tomentosa*
- *Pinnixa tubicola*
- *Portunus xantusii*

Annelida: Polychaeta
- *Amage* sp.
- *Amphicteis scaphobranchiata*
- *Anaitedes williamsi*
- *Aphrodita* sp.
- *Arenicola cristata*
- *Aricidea* sp.
- *Armandia brevis*
- *Axiothella rubrocincta*
- *Chaetozone corona*
- *Chaetozone spinosa*
- *Diopatra splendissima*
- *Diopatra* sp.
- *Eteone dilatae*
- *Euchone limnicola*
- *Glycera americana*
- *Glycera capitata*
- *Glycera tesselata*
- *Goniada littorea*
- *Haploscoloplos elongatus*
- *Hesperonoe complanata*
- *Lumbrineris erecta*
- *Lumbrineris limnicola*
- *Lumbrineris minima*
- *Lumbrineris* sp. 1
- *Lumbrineris* sp. 2
- *Lumbrineris* sp. 3
- *Magelona pitelkai*
- *Mediomastus ambisecta*
- *Megalomma pigmentum*
- *Nephtys caecoides*
- *Nereis latescens*
- *Nereis* sp.
- *Nothria elegans*
- *Notomastus tenuis*
- *Odontosyllis phosphorea*
- *Ophiodromus pugettensis*
- *Paraprionospio* sp.
- *Pectinaria californiensis*
- *Pherusa neopapillata*
- *Pista disjuncta*
- *Pseudocapitella* sp.
- *Scalibregma inflatum*
- *Schistomeringos longicornis*
- *Scolelepis foliosa occidentalis*
- *Scolelepis maculata*
- *Spiophanes bombyx*
- *Synchima* sp.
- *Tharyx moliari*
- *Tharyx multifilis*
- *Tharyx parvus*

Two other sites with very low within-station faunal similarity were Stations 2 and 7; they also had sand substrata. Both Station 2, located in the Mission Bay Channel, and Station 7, located near the Ingraham Street bridge, exhibited temporal variation in species composition. Although the composition at Station 2 fluctuated through time, the polychaete *Lumbrineris minima* was always one of the dominants. Other dominants were: March 1970, *Pherusa neopapillata;* October 1970, *Nereis latescens;* March 1971, *Macoma secta;* April 1972, *Armandia brevis* and *Chaetozone corona;* September 1975, *Tharyx parvus;* and September 1976, *Hippolyte californiensis.* Station 7 showed greater fluctuation of dominant species with time. In March 1970 *Amphiodia occidentalis, Periploma discus,* and *Pherusa neopapillata* were the most abundant species. *Atylus tridens* and *Tharyx parvus* dominated in October 1970 and March 1971. Beginning in April 1972 *Lumbrineris minima* was always one of the dominants and shared dominance during that year with *Chaetozone corona,* with *A. occidentalis* in September 1975, and with *Aricidea* sp. in September 1976.

TABLE 2. Characteristics of Abundant Species from Mission Bay Benthos, 1970–1977.

Species	*# Individuals*	*% Total Composition*	*% Frequency at Stations (10)*	*# Frequency through time (7)*	*Probable feeding mechanism*	*Date of maximum density*	*Maximum density (#/m²)*
Lumbrineris minima	6411	29.0	100	100	Deposit	10/70	485
Euchone limnicola	1770	8.0	100	100	Filter	3/70	216
Atylus tridens	1672	7.6	90	71	Filter	3/70	223
Haploscoloplos elongatus	1644	7.4	100	100	Deposit	4/72	144
Pherusa neopapillata	1448	6.6	90	57	Deposit	3/70	185
Tharyx parvus	1283	5.8	100	100	Deposit	9/75	98
Chaetozone corona	718	3.3	80	57	Deposit	4/72	167
Armandia brevis	606	2.7	90	57	Deposit	4/72	98
Notomastus tenuis	496	2.2	50	86	Deposit	10/70	75
Axiothella rubrocincta	486	2.2	90	86	Deposit	4/72	65
Schistomeringos longicornis	384	1.7	80	43	Detritus	9/75	4
Aoroides columbiae	233	1.1	70	57	Vegetation	9/76	38
Saccoglossus sp.	233	1.1	50	29	Deposit	9/75	5
Solen rosaceus	232	1.1	50	100	Filter	9/76	21

TABLE 3. Synthesis of Station Characteristics of Mission Bay, 1970–1977.

Characteristics	*Stations*									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
No. times sampled	6	6	5	6	5	6	6	6	7	6
Average bottom depth (m)	11	9.5	7.0	6.8	3.5	4.0	4.4	3.5	2.8	4.3
Total no. individuals	1491	1847	1767	2833	3748	2182	1565	2776	1872	2038
Mean density (no./m²)	621	816	884	1180	1874	972	651	1156	660	868
Total biomass (g)	98.45	27.26	48.40	109.85	63.27	66.09	61.04	83.71	76.71	143.85
Mean biomass (g/m²)	41	13	24	46	32	32	25	35	27	60
Total diversity (H')	2.74	4.71	3.31	3.52	3.77	3.51	4.63	3.29	2.69	3.57
Average within-station coefficient of community	.097	.119	.464	.211	.311	.445	.169	.340	.325	.260
Between-station coefficient of community	.133	.304	.472	.506	.359	.461	.426	.416	.396	.425

The three basin sites at the west end of Mission Bay (Stations 3, 4 and 6) were very similar in faunal compositions and physical characteristics. The overlap in species composition and relative abundance of the species was 61% between Stations 3 and 4, 64% between Stations 3 and 6, and 73% between Stations 4 and 6. The fauna remained more predictable through time at these stations than at other ones, and the polychaete *Lumbrineris minima* was always a numerical dominant of the community. *Pherusa neopapillata* shared dominance with *L. minima* at Stations 3 and 4 in March 1970 and at Station 3 in April 1972. *Haploscoloplos elongatus* shared dominance with *L. minima* at all three stations in October 1970, at Stations 3 and 4 in September 1975, and at Station 4 in April 1972. *A. tridens* shared dominance with *L. minima* at Station 6 in April 1972 and in September 1975. In September 1976 *Schistomeringos longicornis* was dominant at both Stations 3 and 6, and *Notomastus tenuis* dominated at Station 4.

TABLE 4. Synthesis of Faunal Composition and Abundance in Mission Bay, 1970–1977.

Station	*Species occurring in 60% or more of all samples*	*5 Most abundant species (all samples pooled)*	*% Contribution to Total no. of individuals*
1	*Branchiostoma californiense*	*Atylus tridens*	59.8
	Cooperella subdiaphana	*Dendraster excentricus*	8.1
	Nephtys caecoides	*Lumbrineris minima*	3.0
		nematods	5.7
		Olivella biplicata	3.5
2	*Glycera* spp.	*Armandia brevis*	19.4
	Haploscoloplos elongatus	*Chaetozone corona*	8.0
	Lumbrineris minima	*L. minima*	7.3
	Macoma secta	*Paraprionospio* sp.	5.4
	Tharyx parvus	*T. parvus*	8.7
3	*Euchone limnicola*	*Atylus tridens*	3.6
	Glycera spp.	*Schistomeringos longicornis*	10.0
	Haploscoloplos elongatus	*E. limnicola*	4.7
	Lumbrineris minima	*H. elongatus*	11.5
	Paraprionospio sp.	*L. minima*	40.2
	Pherusa neopapillata		
	Tharyx parvus		
4	*Atylus tridens*	*A. tridens*	5.1
	Axiothella rubrocincta	*E. limnicola*	7.8
	Euchone limnicola	*H. elongatus*	12.9
	Haploscoloplos elongatus	*L. minima*	36.1
	Lumbrineris minima	*Pherusa neopapillata*	8.8
	Notomastus tenuis		
	Protothaca staminea		
5	*Atylus tridens*	*E. limnicola*	5.5
	Chaetozone corona	*H. elongatus*	5.0
	Euchone limnicola	*L. minima*	33.3
	Haploscoloplos elongatus	*P. neopapillata*	11.0
	Lumbrineris minima	*Saccoglossus* sp.	6.0
	Notomastus tenuis		
	Pherusa neopapillata		
	Tharyx parvus		

TABLE 4. Synthesis of Faunal Composition and Abundance in Mission Bay, 1970–1977.—Continued

Station	*Species occurring in 60% or more of all samples*	*5 Most abundant species (all samples pooled)*	*% Contribution to Total no. of individuals*
6	*Atylus tridens*	*A. tridens*	11.5
	Euchone limnicola	*Chaetozone corona*	5.3
	Glycera spp.	*H. elongatus*	8.7
	Haploscoloplos elongatus	*L. minima*	39.8
	Lumbrineris minima	*P. neopapillata*	5.3
	Notomastus tenuis		
	Pherusa neopapillata		
	Tagelus californianus		
7	*Amphiodia occidentalis*	*Atylus tridens*	4.4
	Cooperella subdiaphana	*Chaetozone corona*	11.7
	Dendraster excentricus	*H. elongatus*	6.8
	Haploscoloplos elongatus	*L. minima*	23.7
	Lumbrineris minima	ostracods	3.9
	Lytechinus anamesus		
	Notomastus tenuis		
8	*Axiothella rubrocincta*	*A. rubrocincta*	8.4
	Euchone limnicola	*E. limnicola*	18.3
	Haploscoloplos elongatus	*H. elongatus*	11.6
	Lumbrineris minima	*L. minima*	26.8
	Musculus senhousei	*Pherusa neopapillata*	16.5
	Solen rosaceus		
	Tagelus californianus		
9	*Edwardsiella californica*	*E. limnicola*	11.1
	Euchone limnicola	*L. minima*	34.2
	Lumbrineris minima	*Notomastus tenuis*	3.8
	Musculus senhousei	*S. rosaceus*	2.5
	Solen rosaceus	*T. parvus*	34.8
	Tharyx parvus		
10	*Edwardsiella californica*	*E. limnicola*	22.7
	Euchone limnicola	*Haploscoloplos elongatus*	9.0
	Lumbrineris minima	*L. minima*	27.1
	Musculus senhousei	ostracods	6.0
	Notomastus tenuis	*S. rosaceus*	6.5
	Solen rosaceus		
	Tharyx parvus		

Station 5, located in the middle of Sail Bay, showed some distinctions from the other stations with predominantly muddy sediment. The sediment sample often contained rooted mats of the eel grass, *Zostera marina*. This station also exhibited the highest infaunal densities of all stations. *Lumbrineris minima* was always a dominant species, and it shared dominance with *Pherusa neopapillata* in March and October 1970, with *Aricidea* sp. in April 1972, and with the amphipods *Atylus tridens* in September 1975 and *Photis brevipes* in September 1976.

The back bay stations (8, 9 and 10) also showed a high similarity among their fauna. Faunal similarity was 51% between Stations 8 and 9, 52% between Stations 9 and 10, and 53% between Stations 8 and 10. *Lumbrineris minima* was the dominant form at each station on all sampling dates. Dominance was shared with *Euchone limnicola* at Station 8 in March 1970 and April 1972, and at Station 10 in March 1970 and January 1977. *Haploscoloplos elongatus* was abundant in October 1970 at Station 8 and in March 1970 at Station 10. Other dominants were *Axiothella rubrocincta* in April 1972 and September 1976 at Station 8, and April 1972 at Station 10; *Tharyx parvus* at Station 9 generally; *Solen rosaceus* in October 1970 at Station 9 and at Station 10 in September 1975 and September 1976; *Acteocina inculta* in January 1970 at Station 9; *Edwardsiella californica* in October 1970 at Station 10; *Zaolutus actius* in April 1972 at Station 10; and *Musculus senhousei* in January 1977 at Station 10. Due primarily to the greater abundance of various bivalves at Station 10, it had the highest biomass values within Mission Bay.

Community Ordination

Since the benthic fauna of the entire bay is dominated by the polychaete *Lumbrineris minima,* there is a high degree of similarity among the stations. Two channel stations at the entrance to the bay (Stations 1 and 2) are easily separated from the other stations (Figure 2). Stations 1 and 2 are also separated from each other. These stations are exposed to much greater instability in the sediment due to higher current flow and more frequent dredging. It is likely that no stable community exists at these stations. The overall mean index of similarity among all stations is 0.389; if the outer bay Stations 1 and 2 are eliminated from consideration, the average similarity among the other stations is 0.492. Although Station 7 differs from the remainder of the stations in having a predominantly sandy substratum, it still exhibits high similarity with the rest of the infauna. Thus it appears that within the bay proper a single soft bottom community exists dominated by the polychaete *L. minima,* but variations in compositions occur both spatially and temporally.

Comparison With Fauna of Nearby Bays

Surveys of the benthic fauna of six bays in southern California and northern Baja California have been described during the past 22 years. A comparison of these faunas to that found in this study at Mission Bay indicates an average overlap of about 22% in the distribution of species, and at least an additional 25% overlap at the generic level. Of the 13 most abundant identified species in Mission Bay (Table 2), three occurred in all six embayments *(L. minima, H. elongatus, A. brevis),* six others were present in at least 50% of these sites *(A. rubrocincta, C. corona, S. longicornis, T. parvus, A. colombiae,* and *S. rosaceus),* and one *Atylus tridens* was reported only from Mission Bay. There is no evidence to suggest that the fauna of Mission Bay is markedly different from that of other bays in southern California, nor does it appear to be richer in species composition. Although Mission Bay is less polluted than other southern California bays, its fauna does not appear to be strikingly different.

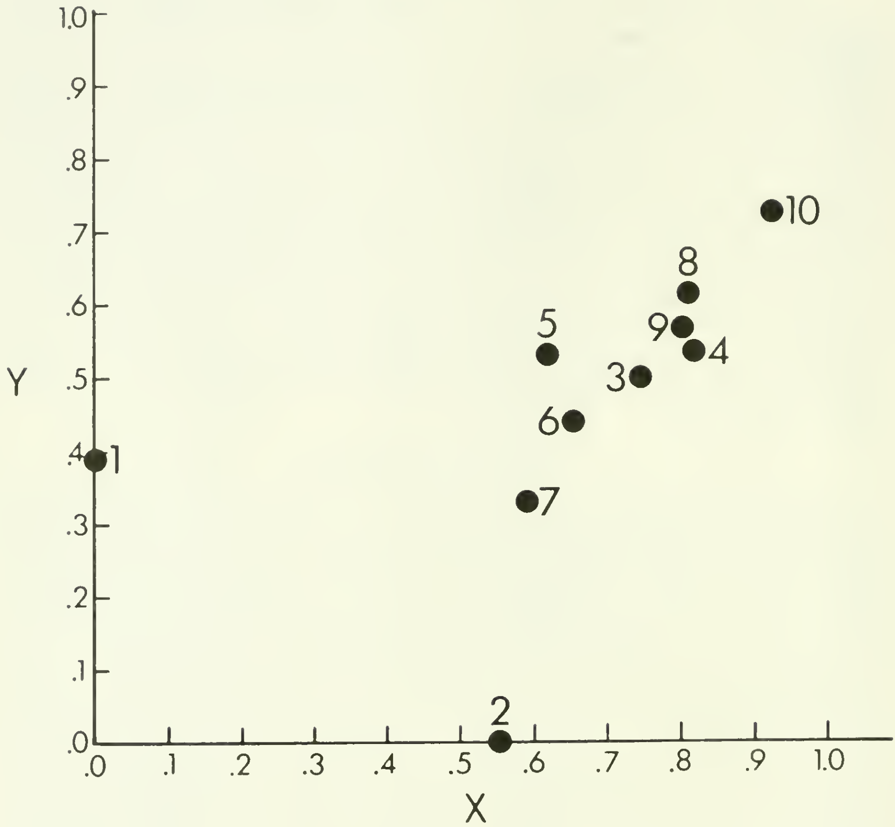

FIGURE 2. Two-dimensional ordination of benthic infauna on the basis of *x* and *y* coordinates for Mission Bay during 1970–1977.

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Calif. Fish and Game 69(1): 18–22 1983

BEHAVIORAL RESPONSE OF JUVENILE CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA,* TO TRASH RACK BAR SPACING [1]

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The behavioral response of juvenile chinook salmon, *Oncorhynchus tshawytscha,* to vertical trash racks having interbar spacings ranging from 5.1 to 30.5 cm is reported. Experiments were conducted in a laboratory channel with an average water velocity of 32 cm/sec under light intensities of 14.0 and 1.0 $\times$ 10^{-2} footcandles. Transit times were not significantly different between light levels, but differences between bar spacings were significant. Observed changes in rheotaxic posture and hesitancy to pass through a trash rack with bar spacing less than 15 cm would increase the susceptibility of juvenile fish to predation.

INTRODUCTION

Despite pleas for conservation, demands on our nation's water resources for electrical power generation, industrial, municipal, and agricultural use have continued to increase, and this has led to a proliferation of water intake and diversion facilities. During the past 30 years considerable effort, time, and money have been devoted to the design and development of water intake structures and associated fish salvage systems. During this period of development, however, one aspect of virtually all water intake systems has been neglected—the development of biological criteria for the design of trash racks. Our observations at existing water intake facilities indicate that fish may hesitate to pass through a trash rack, and thus become susceptible to predation. This predation may reduce the operating efficiency of an otherwise acceptable fish salvage system.

The objective of this study was to determine the behavioral response of juvenile chinook salmon, *Oncorhynchus tshawytscha,* to vertical trash racks. The design of the study consisted of regulating trash rack bar spacing and light intensity under laboratory conditions to determine (i) the response of juvenile salmon to various trash rack bar configurations, and (ii) the influence of light intensity on the response pattern.

MATERIALS AND METHODS

The juvenile chinook salmon (mean fork length = 45.2 mm, S.D. = 5.5, n = 125) used in these studies were collected with beach seines from the Sacramento River near Red Bluff, California. Before testing, the fish were held for a minimum of 1 week in a 500-liter fiberglass tank maintained at a temperature of 15.0 ± 0.5° C. While being held, fish were fed brine shrimp regularly. All fish were fed to satiation before the start of each experiment; no food was provided during testing.

Experiments were conducted in an oval flume 16 m in circumference, 1.0 m wide and 0.4 m deep (Figure 1). Flow was generated by a motor-driven, six-

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blade paddle wheel. Observations were made through glass viewing ports along the inner wall of the flume. Light intensity in the experimental system was controlled with a rheostat and eight 75-watt incandescent bulbs equally spaced around the circumference of the flume. Illumination at the water surface, 1 m from the light sources, was continuously variable from 14.0 to $< 1 \times 10^{-4}$ footcandles. Light intensity was measured at the water surface in all tests using a digital photometer (Gamma Scientific Model 820 A) with a footcandle detector head (Model 820-30). Water temperature in the flume was maintained at 15.0 ± 0.5° C by a water cooler.

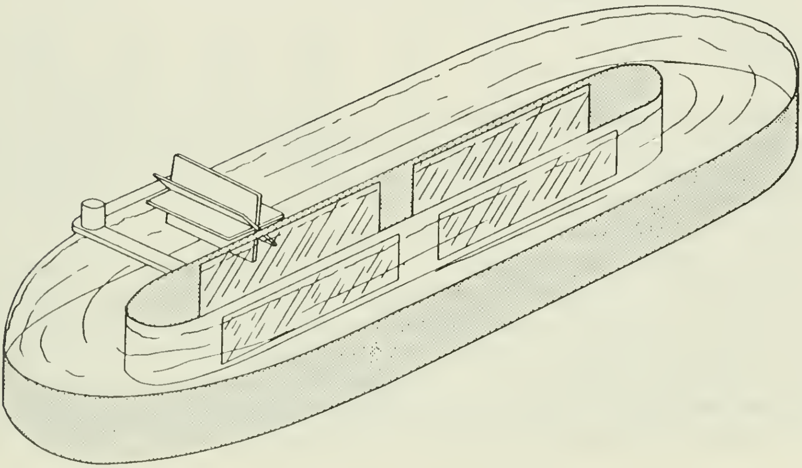

FIGURE 1. Diagram of the experimental flume.

In each experiment, 12–15 fish were placed in the flume and allowed 24 h under static conditions before testing. Following this acclimation period, a simulated vertical trash rack was positioned in a linear section of the flume. Simulated trash racks consisted of wooden dowels 1 cm in diameter painted black. Dowels were positioned in vertical arrays having interbar spacings of 5.1, 7.6, 15.2, 22.9, and 30.5 cm. Following insertion of the trash rack, water flow was started and fish were allowed an additional 15 min period of acclimation. Approach velocity at the trash rack averaged 32 cm/sec and ranged from 26 to 39 cm/sec.

The behavioral response of fish was determined by measuring the time required for a fish to traverse an 80 cm observation zone directly upstream from the trash rack. In addition, the rheotaxic orientation of each fish was recorded as it entered the observation zone and again as it passed through the trash rack. Each experiment was conducted until 50 observations were completed. Only observations of fish encountering the trash rack from the upstream side were recorded. The behavioral response of fish passing through the observation zone in the absence of a trash rack acted as a control. Replicate experiments were conducted for each trash rack configuration under light intensities of 14.0 and 1.0×10^{-2} footcandles.

RESULTS AND DISCUSSION

A two-way analysis of variance of the relationship between trash rack bar spacing and transit time (Figure 2), transformed using logarithms, at light intensities of 14.0 and 1.0×10^{-2} footcandles indicated that transit times were not significantly different ($F = 0.69$; $P = 0.41$) between the two light levels but that differences between bar spacings were significant ($F = 39.27$; $P = 0.001$). Significant differences in transit times between the various trash rack bar spacings (combined for both light levels) were examined using Duncan's multiple range test with the following result (bar spacings connected by an underscore are not significantly different, $\alpha = 0.05$):

Bar spacing (cm)	*5.1*	*7.6*	*15.2*	*22.9*	*30.5*	*control*
Mean transit time (sec)	6.7	4.3	2.9	2.6	3.3	3.0
	___	___	___________	___________	___________	___________

Transit times were significantly longer for trash rack bar spacings of 5.1 and 7.6 cm than for bar spacings 15 cm or greater, indicating that chinook salmon are responding behaviorally to the smaller bar spacings as evidenced by a hesitancy prior to passage through the trash rack.

The hypothesis that trash rack bar spacings of less than 15 cm act as a behavioral barrier for juvenile chinook salmon was supported by the data on their rheotaxic response upon encountering the various trash rack bar arrangements (Table 1). The fish usually entered the observation zone facing downstream (negatively rheotaxic). This orientation was generally maintained as fish passed through trash racks having bar spacings of 15.2 cm or greater. In contrast, fish encountering a trash rack with bar spacings of either 5.1 or 7.6 cm typically reversed direction and passed through the trash rack tail first.

TABLE 1. Summary of Juvenile Chinook Salmon Rheotaxic Response and Transit Time in Response to Various Trash Rack Bar Spacings.

Bar spacing cm	*Percent negative rheotaxis* — *Entering 80 cm zone*	*Percent negative rheotaxis* — *Exiting 80 cm zone*	*Percent change in orientation*	*Mean transit time for 80 cm zone (sec)*	*Standard Deviation*
Light: 14.0 footcandles					
5.1	86	46	40	6.50	5.86
7.6	93	64	29	4.32	3.06
15.2	98	90	8	2.77	1.89
22.9	97	94	3	2.56	1.40
30.5	89	79	10	3.38	2.76
Control	95	84	11	3.09	2.11
Light: 1.0×10^{-2} footcandles					
5.1	76	52	24	7.53	7.98
7.6	84	64	20	4.35	3.51
15.2	68	68	0	3.57	2.03
22.9	88	80	8	2.92	1.25
30.5	84	72	12	2.95	1.30
Control	84	76	8	2.70	0.95

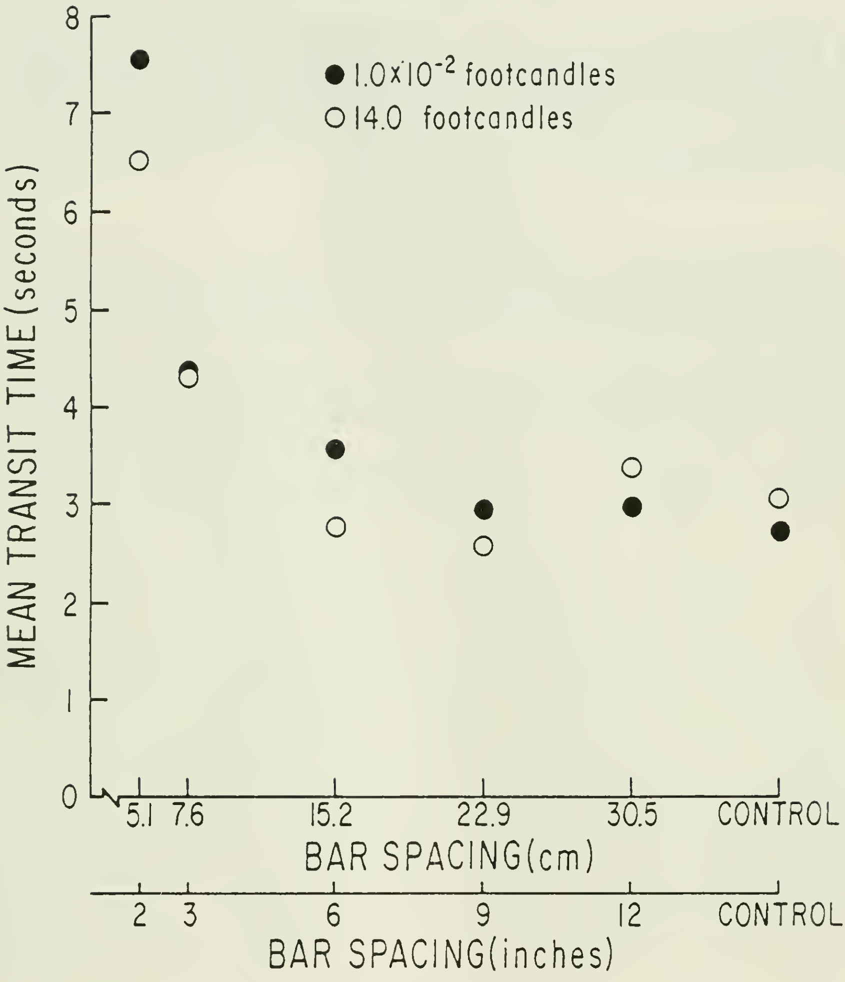

FIGURE 2. Mean transit time for juvenile chinook salmon exposed to various vertical trash rack bar spacings at light intensities of 14.0 and 1.0×10^{-2} footcandles.

We contend that the change in rheotaxic posture and hesitancy to pass through a trash rack with bar spacing less than 15 cm increases the susceptibility of juvenile fish to predation. Our observations made at the trash rack (9.0 cm interbar spacing) of the John E. Skinner Delta Fish Protective Facility located near Tracy, California, support the predation hypothesis. Juvenile chinook salmon, American shad, *Alosa sapidissima,* and threadfin shad, *Dorosoma petenense,* approaching the trash rack frequently changed their orientation to a positively rheotaxic posture and maintained position in the flow before passing through the trash rack tail first. Predation by yearling and adult striped bass, *Morone saxatilis,* at the trash rack was extensive.

Our research with juvenile chinook salmon suggests that designing trash racks with interbar spacing greater than 15 cm should reduce predation of that species. We recommend similar experiments with other species (e.g., juvenile American shad, striped bass, alewife), and investigation of the behavioral effect of angled trash racks (louvers) in research efforts toward increasing the fish salvage efficiency of water intakes and diversion facilities.

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DISTRIBUTION OF FISHES IN STREAMS OF THE WALNUT CREEK BASIN, CALIFORNIA [1]

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The distribution of fishes in 27 sampling sites on 10 streams of the Walnut Creek basin, Contra Costa County, California, was determined during October and November 1980. Of 20 fish species collected, 13 (65%) were exotic to California, and 7 were native. Pumpkinseed, *Lepomis gibbosus,* were collected in the basin, a new locality for this species in California. The number of species in stream sections altered by flood control levees was greater than in undisturbed sections. The high fish species diversity in the Walnut Creek basin is not typical of other small Central Valley streams.

INTRODUCTION

In recent years several studies have examined the distribution of native and exotic fishes of the Central Valley (Turner and Kelley 1966; Moyle 1973, 1976 *a,b*; Moyle and Nichols 1973, 1974): however, information is limited on the distribution of fishes in streams of the Walnut Creek basin located at the western extreme of the Central Valley (Figure 1). Ayres (1855) identified the presence of steelhead trout/rainbow trout, *Salmo rivularis* (=*Salmo gairdneri*), "back of Martinez, toward the foot of Monte Diablo." The Walnut Creek basin lies between Martinez and Mt. Diablo and is the probable location of Ayres' reference. Steelhead trout and coho salmon, *Oncorhynchus kisutch,* were sighted during spawning migration in streams within the Walnut Creek drainage during the 1950's to mid-1960's (Calif. Dept. of Fish and Game files 1976–1979). Limited sampling of Walnut Creek and its tributaries by the California Department of Fish and Game revealed the occurrence of 11 species (Table 1). The restricted nature of previous surveys with respect to methodology, number of collecting localities, and diversity of stream habitats sampled, prompted this more comprehensive survey.

STUDY AREA

The study was conducted at 10 streams in the Walnut Creek basin of central Contra Costa County (Figure 1). Elevations ranged between 1 m at the confluence of Walnut Creek and Suisun Bay, and 232 m at the headwaters of Bolinger Creek. The 466-km^2 basin drains into Suisun Bay, an estuarine transition zone between the Sacramento-San Joaquin River Delta and San Francisco Bay. Walnut Creek is the principal stream of the drainage basin. Tributaries to Walnut Creek include Pacheco, Pine, Galindo, San Ramon, Las Trampas, Tice, Lafayette, Green Valley, Sycamore, San Catanio, Bolinger, and Grayson creeks. These streams are perennial during years of normal precipitation.

Much of the Walnut Creek basin has been developed for residential, commercial, and industrial uses. Urbanization of the basin, involving extensive stream channel modification for flood control purposes, has eliminated much of the

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historical riparian and aquatic stream habitats. Approximately 95% of the Walnut Creek-San Ramon Creek stream channel has been altered by levees or concrete channels (U.S. Army Corps of Engineers 1979). Portions of the tributary streams have also been modified for flood control. Subsequent to stream modification activities, plant succession has resulted in limited revegetation of certain levee sections.

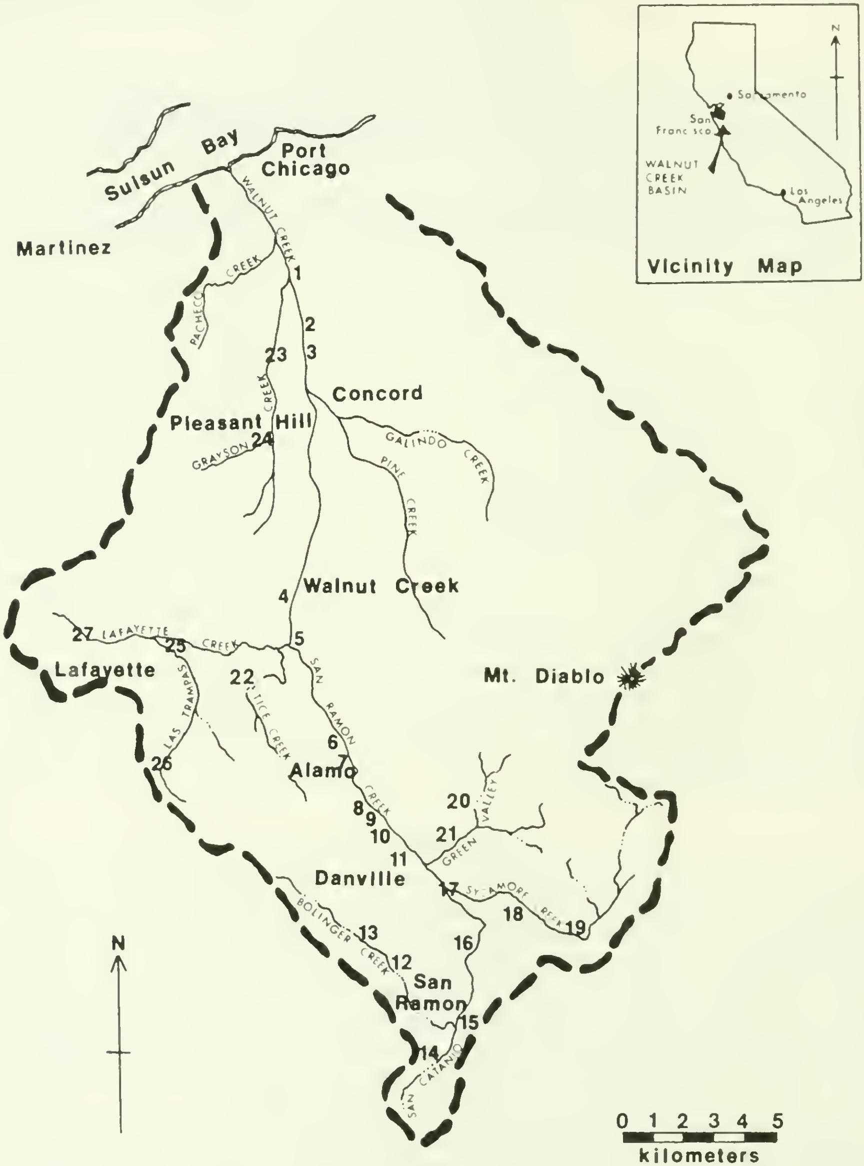

FIGURE 1. General map of the Walnut Creek basin, Contra Costa County, California. Numbers indicate sampling sites.

TABLE 1. Historical Records of Fish Species Occurring in Streams of the Walnut Creek Basin, California [1].

Species	*Historical Records*
Native Species	
Steelhead/Rainbow trout *(Salmo gairdneri)*	1855[2], 1950's to mid-1960's
Coho salmon *(Oncorhynchus kisutch)*	1956, 1950's to mid-1960's
Hitch *(Lavinia exilcauda)*	1978
Sacramento western roach *(Hesperoleucus symmetricus)*	1939[3], 1942[5], 1945[4], 1946[3], 1976, 1977, 1978
Sacramento sucker *(Catostomus occidentalis)*	1942[5], 1945[4], 1977, 1978
Threespine stickleback *(Gasterosteus aculeatus)*	1978
Exotic Species	
Goldfish *(Carassius auratus)*	1977, 1978
Carp *(Cyprinus carpio)*	1977, 1978
Golden shiner *(Notemigonus crysoleucas)*	1977
Mosquito fish *(Gambusia affinis)*	1942[5], 1945[4], 1977, 1978
Green sunfish *(Lepomis cyanellus)*	1945[5], 1976, 1977, 1978
Bluegill *(Lepomis macrochirus)*	1977, 1978
Redear sunfish *(Lepomis microlophus)*	1978[6]

[1] California Department of Fish and Game files (1976–1979)
[2] Ayres (1855)
[3] Hopkirk (1974)
[4] W. I. Follett (pers. commun.)
[5] California Academy of Sciences fish collection
[6] Species not recorded during present study

METHODS

Twenty-seven sites were sampled for fish between 1 October and 21 November 1980 (Table 2). Representative riffle, glide, and pool habitats were sampled throughout the drainage basin.

A 6-mm mesh seine, in combination with a portable Smith-Root Type V electroshocker, was used at sites with depths to 1 m. Sites with greater depths were sampled with 13- and 19-mm mesh gill nets 10 m in length. Gill nets were set at sunset and retrieved at sunrise the following morning. A hand dip net was used to sample intermittent pools characteristic of the headwaters of smaller tributary streams. The number and size range of individuals of each species collected were recorded for each sampling locality. Representatives of each species were preserved in 10% formalin for future reference.

Sixteen environmental variables were recorded at each sampling site to relate fish distribution to habitat characteristics. These included: (1) mean depth; (2) maximum depth; (3) width; (4) percentage of stream bottom composed of rooted aquatic vegetation; (5) percentage of stream surface covered with floating aquatic vegetation; (6) percentage of water surface shaded for the majority of the daylight period; (7) percentage of area pools; (8) percentage of area riffles; (9) percentage of bottom silt; (10) percentage of bottom sand; (11) percentage of bottom gravel; (12) percentage of bottom cobbles; (13) percentage of bottom bedrock; (14) turbidity; (15) quality and amount of cover; and (16) degree of human disturbance. A scaled rating system (0–5) was used

TABLE 2. Number of Native (N) and Introduced (I) Fishes Collected at 20 Sampling Sites in

	Walnut Ck. Site				*San Ramon Ck. Site*			
Species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Ictaluridae								
White catfish (*Ictalurus catus*) I			13 (140–152)					
Balck bullhead (*Ictalurus melas*) I			2 (220–245)		2 (241–254)	17 (152–508)	2 (240–250)	6 (203–305)
Cyprinidae								
Goldfish (*Carassius auratus*) I				1 (178)	2 (203–254)			
Golden shiner (*Notemigonus crysoleucas*) I			1 (140)		2 (137–140)			1 (127)
Carp (*Cyprinus carpio*) I			3 (150–190)					
Sacramento squawfish (*Ptychocheilus grandis*) N	1 (254)	1 (229)	3 (191–280)					
Sacramento blackfish (*Orthodon microlepidotus*) N			1 (216)					
Hitch (*Lavinia exilicauda*) N	4 (51–127)	18 (70–165)	92 (64–225)	1 (114)				25 (57–133)
California roach (*Hesperoleucas symetricus*) N			2 (64)	46 (38–107)	25 (51–89)	1 (152)		
Catostomidae								
Sacramento sucker (*Catostomus occidentalis*) N			5 (121–180)	2 (95–102)	9 (260–315)	19 (152–381)	8 (258–304)	4 (178–318)
Cyprinodontidae								
Rainwater killifish (*Lucania parva*) I		1 (36)						
Poecilidae								
Mosquitofish (*Gambusia affinis*) I			5 (13–25)					
Atherinidae								
Mississippi silverside (*Menidia audens*) I	75 (102–152)	7 (83–108)	3 (83–89)					
Centrachidae								
Green sunfish (*Lepomis cyanellus*) I				2 (95–97)	15 (108–191)	1 (178)		5 (110–130)

Streams of the Walnut Creek Basin, California (Size Range (TL mm) in Parenthesis)[1].

					Green		*Trice*	*Grayson*		*Las*	
				Sycamore	*Valley Ck.*		*Ck.*	*Ck.*		*Trampas*	*Lafaye*
	San Ramon Ck. Site			*Site*	*Site*	*Site*	*Site*	*Site*	*Site*	*Site*	*Site*
9	*11*	*16*	*17*	*18*	*20*	*21*	*22*	*23*	*24*	*25*	*27*
	1 (266)							6 (40–127)			
							1 (102)				
								1 (214)			
100 (76–127)								17 (83–159)			
			31 (44–121)		12 (51–127)	50 (51–104)	25 (51–102)			100 (53–79)	
										20 (102–178)	
								1 (36)			
			1 (32)	10 (25–32)				50 (44–55)			
9 (109–117)								2 (25–178)			

TABLE 2. Number of Native (N) and Introduced (I) Fishes Collected at 20 Sampling Sites in

Species	*Walnut Ck. Site* *1*	*2*	*3*	*4*	*San Ramon Ck. Site* *5*	*6*	*7*	*8*
Bluegill (*Lepomis macrochirus*) I				6 (83–108)				
Pumpkinseed (*Lepomis gibbosus*) I								
Percichthyidae								
Striped bass (*Morone saxatilis*) I	2 (152–203)	1 (95)						
Gobiidae								
Yellowfin goby (*Acanthogobius flavimanus*) I	9 (127–178)	3 (127–152)						
Cottidae								
Prickly sculpin (*Cottus asper*) N	1 (38)	4 (25–44)						
Gasterosteidae								
Threespine stickleback (*Gasterosteus aculeatus*) N		12 (25–44)	1 (13)	8 (44–51)				

[1] No fish were collected at sites 10 and 15 on San Ramon Creek, 12 and 13 on Bolinger Creek, 14 on San Catanio

to simplify the quantification of three evironmental variables. A turbidity rating of 0 is very clear, 5 extremely turbid. The quality and amount of cover available to fish is rated 0 for no cover and 5 for abundant and diverse cover. A human disturbance rating of 0 implies no noticeable human disturbance, while 5 denotes significant alteration of the stream channel and riparian habitat. All scaled ratings were qualitative.

RESULTS AND DISCUSSION

Twenty fish species were collected from 27 sites in the Walnut Creek basin (Table 2). Bolinger Creek and San Catanio Creek, two of the headwater streams, were without fish. Seven of the 20 species collected were native to California. Thirteen species, or 65% of the total species collected, were exotics introduced into California.

Only one specimen of Sacramento blackfish, *Orthodon microlepidotus,* was collected, a species considered rare in the drainage basin. Three species (white catfish, *Ictalurus catus;* bluegill, *Lepomis macrochirus;* and pumpkinseed, *Lepomis gibbosus*) although not numerically rare, were collected at only one locality.

Streams of the Walnut Creek Basin, California (Size Range (TL mm) in Parenthesis)[1].—Continued

San Ramon Ck. Site				Sycamore Site	Green Valley Ck.		Trice Ck. Site	Grayson Ck.		Las Trampas Site	Lafayette Site
					Site	Site		Site	Site		
9	*11*	*16*	*17*	*18*	*20*	*21*	*22*	*23*	*24*	*25*	*27*
3 (97–140)											
		100 (32–44)	100 (25–44)			10 (25–38)	30 (25–61)	6 (25–32)	25 (25–38)	100 (25–51)	12 (51–64)

Creek, 19 on Sycamore Creek, and 26 on Las Trampas Creek.

The occurrence of the exotic pumpkinseed in the Walnut Creek basin represents a new locality for this species in California. Pumpkinseed have not been previously recorded from the Central Valley, although on 11 November 1980, personnel of the California Department of Fish and Game captured two sunfish believed to be pumpkinseed from Beaver Slough in the Sacramento-San Joaquin River Delta (D. Kohlhorst, Associate Fishery Biologist, California Department of Fish and Game, pers. commun.). The pumpkinseed was formerly known to occur only in the Klamath River drainage, in Honey Lake and Susan River in Lassen County, and in Big Bear Lake in San Bernardino County (Moyle 1976*b*). Fish collection records indicate that at one time this species occurred in a pond at Golden Gate Park in San Francisco (California Academy of Sciences fish collection). The establishment of pumpkinseed in the Walnut Creek basin is probably the result of a recent introduction and not a natural range expansion.

Historical records provide evidence that steelhead trout and coho salmon formerly occurred within the basin (Table 1). Sampling during this study, however, failed to collect either species. It is likely that the extensive modification of streams within the basin for flood control purposes has eliminated suitable salmonid habitat. Among adverse impacts associated with flood control activities have been channel modification, creation of barriers to fish migration, elimination of riparian vegetation, and deterioration of water quality. Erosion and siltation of some streams within the basin is a noticeable consequence of rapid urbanization. All of these factors, no doubt, have contributed to the elimination of salmonids.

Historical records also indicate the presence of redear sunfish, *L. microlophus,* in the drainage (Table 1). Although habitats typical of this species were sampled, no specimens were collected. If this species is present in the basin, it is likely uncommon.

Sixteen environmental variables were recorded at each collection site, for the purpose of comparing the occurrence and distribution of fishes to habitat characteristics. The wide range in values of most of these variables, the limited number of collection sites with fish (n=20), and the highly variable distribution of most species prevented the development of statistically significant correlations between the distribution of each species and its habitat or correlations between and among species. Although statistical correlations were not evident, general conclusions concerning fish distribution can be made.

Species often found in estuarine environments were collected at sites 1 and 2 at the confluence of Walnut Creek and Suisun Bay (Figure 1). These two sites are characterized by diel tidal fluctuations, a silt substrate, turbid water, and limited aquatic vegetation. Estuarine species collected include the yellowfin goby, *Acanthogobius flavimanus*; rainwater killifish, *Lucania parva*; prickly sculpin, *Cottus asper*; Mississippi silverside, *Menidia audens*; and striped bass, *Morone saxatilis*. These species tolerate widely fluctuating salinity levels, high water temperatures, and turbid water conditions (Moyle 1976*b*).

Within the Walnut Creek basin species diversity was greatest in Walnut Creek at site 3. Sixty percent of all species collected were recorded at this locality (Table 2). Site 3, located in a stream section modified by levees, was characterized by low turbidity, a favorable pool to riffle ratio (40 : 60), a substrate consisting of 90% sand and gravel, and abundant cover. Of the 12 species collected at site 3, 6 were native and 6 were exotic. Moyle and Nichols (1974) found that high densities and diversity of exotic fish species in a given area excluded native species. Sacramento squawfish, *Ptychocheilus grandis,* are usually rare or absent in disturbed habitats where exotic fish are common, especially carp, *Cyprinus carpio* (Moyle and Nichols 1973). At site 3, however, squawfish and carp were found to be most abundant when they occurred in the same pools. The diversity of both native and exotic fishes collected at site 3 suggests that habitat and food diversity is high, thus reducing competition among species.

Exotic sunfishes were recorded at sites characterized by deep turbid pools with heavily silted substrates. Sites 4, 5, 6, 8, and 9, in Walnut Creek and San Ramon Creek exemplified these conditions.

Threespine stickleback, *Gasterosteus aculeatus,* the most widely distributed species in the basin, was collected at 41% of the sites sampled. Densities were highest at sites 16, 22, 24, and 25, which were characterized by low turbidity, abundant and diverse types of cover available to fish, and a high percentage of the water surface shaded.

Sacramento western roach, *Hesperoleucus symmetricus,* while collected at 30% of the sites sampled, were most abundant at sites 17, 21, and 25, characterized by heavily silted substrates and extensive aerial coverage of rooted and floating vegetation, especially floating mats of algae. These sites contained few other species. Moyle (1976*b*) found that the roach was conspicuously absent from stream sections containing other large fish. Filamentous algae constitute the main food in the roach diet (Moyle 1976*b*).

Diversity of species tended to be higher at sites with a high rating of human disturbance when compared to sites with low disturbance ratings. The ability of exotic species to colonize disturbed habitats may account for this increased diversity. Revegetation of disturbed stream sections has increased shading and the quality and quantity of cover available to fish, thus improving the suitability of these areas for fish colonization.

CONCLUSIONS

Fish diversity in the Walnut Creek basin is high when compared with diversity in other Central Valley drainages of similar size. Moyle and Nichols (1976) recorded 24 fish species from 167 sampling locations in a seven county area of the Sierra Nevada foothills. Aceituno *et al.* (1973) collected 13 fish species from Alameda and Coyote creeks, two tributaries to San Francisco Bay. Scoppettone and Smith (1978) recorded 18 species in these streams. The highly diverse fish fauna of the Walnut Creek basin, consisting as it does of native and exotic species is unusual, and is probably related to the highly variable stream habitat characteristics. Moyle (1976*c*) also found that in Rush Creek in the Pit River drainage, the numbers and biomass of some species were significantly lower in channelized stream sections when compared to unchannelized sections. The diversity of species at site 3 in Walnut Creek suggests that exotic and native species are not mutually exclusive if habitat diversity is great enough to reduce competition.

The pumpkinseed collected in the Walnut Creek basin represents a new locality for this species in California. Further sampling is necessary to determine whether this species has established a viable population within the drainage.

Unfortunately, historical records of the fishes of the Walnut Creek basin were extremely limited in extent and cursory in detail. Perhaps if this type of information had been available, more consideration would have been given to the protection and enhancement of aquatic and riparian habitats during development of the basin, especially flood control measures. This is particularly true considering the probable effects of channelization and urban development on the salmonid populations that historically inhabited the basin.

Some opportunities do exist for aquatic and riparian habitat improvements within the Walnut Creek basin. Revegetation of levees in channelized stream sections with native riparian plant species would improve habitat. The establishment and enforcement of land use controls could reduce erosion and improve water quality within the drainage. Also, the feasibility of installing fish ladders over man-made barriers with the goal of reestablishing salmonid populations within the drainage should be studied.

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NOTES ON THE FEEDING HABITS OF THE YELLOWTAIL ROCKFISH, *SEBASTES FLAVIDUS,* OFF WASHINGTON AND IN QUEEN CHARLOTTE SOUND [1]

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***Sebastes flavidus* caught in bottom trawls off Washington fed almost exclusively on euphausiids. Those caught in midwater trawls in Queen Charlotte Sound had eaten euphausiids as well as pelagic and benthic fishes. Our limited data suggested that feeding occurred mainly during the night or early morning hours, although some feeding probably occurred during daytime as well. Diel changes in behavior associated with feeding on vertically migrating prey may explain day-night differences in catches of some rockfishes.**

INTRODUCTION

Sebastes flavidus (Ayres), the yellowtail rockfish, occurs along the west coast of North America from the Gulf of Alaska to San Diego, California (Hart 1973) and is abundant between southern Oregon and Cape Spencer, Alaska, especially at depths of 90–180 m (Alverson, Pruter and Ronholt 1964). It was the most important species in the rockfish catches of Oregon trawlers from Cape Elizabeth, Washington to Florence, Oregon, averaging 37% of the catch from 1963 to 1971 (Niska 1976). The biomass of yellowtail rockfish was estimated to be higher than any other rockfish species in 1977 from 91 to 475 m depth off southern Washington and second only to *S. pinniger* off northern Washington and to *S. saxicola* from Cape Blanco, Oregon to Cape Mendocino, California (Gunderson and Sample 1980).

METHODS

Fish were collected (a) by the M/V *Pacific Raider* from Queen Charlotte Sound (ca. 51° 29'N, 128° 43'W) on 23–26 September 1976, in a Herman Engel midwater trawl (50-m foot and headropes) fished from 0 to 44 m off the bottom where the average depth was 146 m, and (b) by the R/V *Oregon* off Washington at two locations (ca. 48° 10'N, 125° 39'W and 48° 05'N, 125° 36'W) on 18–20 April 1977 in a Nor'Eastern otter trawl (32.3-m foot and 27.7-m headropes) at an average depth of 116 m. Seven collections were made during day and night periods at each area (Table 1).

A total of 210 *S. flavidus* was sampled for stomach content analysis, 96 from Queen Charlotte Sound and 114 from off Washington. The fork length of each fish was recorded to the nearest 0.1 cm; lengths from all collections ranged from 34 to 57 cm. Average lengths were similar within each area. All *S. flavidus* from individual hauls were weighed together; average weights were 1860 g from Queen Charlotte Sound and 1631 g from off Washington. Stomach contents

[1] Accepted for publication October 1981.

were removed and preserved in 10% formalin immediately after recapture at sea. No *S. flavidus* were observed with everted stomachs.

Stomach fullness was estimated using a numerical scale from 0 to 3 (where 0 = empty, 1 = partly full, 2 = full stomach, and 3 = distended stomach); stages of digestion were scaled from 1 (undigested) to 3 (well digested) according to Tyler and Pearcy (1975). Individual food items were identified to species when possible.

Data on food habits are expressed as: (i) percent composition by wet weight of crustaceans, fishes, and all other taxa combined; (ii) frequency of occurrence of a taxon based on all fish examined containing food; and (iii) wet weight of stomach contents as a proportion of fish weight. Wet weights were measured on formalin-preserved organisms after excess moisture was removed by blotting on absorbent paper.

RESULTS

Crustaceans comprised 93% of the wet weight of food from *S. flavidus* stomachs collected off Washington; fishes and all other food items comprised only 7%. Euphausiids were the dominant prey. *Thysanoessa spinifera* and *Euphausia pacifica* occurred in over 85% of the fish containing food (Table 2). The prey listed as Euphausiacea in Table 2 were too well digested to identify to species but are assumed to be the same species. *Pasiphaea pacifica* was the only species of shrimp present. Of the fishes eaten, only *Hemilepidotus,* a benthic sculpin, was identified; others were too digested to identify.

Fishes and crustaceans were both major food sources of *S. flavidus* from the Queen Charlotte Sound area on a wet weight basis, comprising 55% and 44% of the diet. *T. spinifera,* the predominant crustacean by weight, was about twice as frequent as *E. pacifica* or unidentified Euphausiacea (Table 2). *Pandalus jordani* was the most common shrimp. Fishes occurred in 46 of the 96 stomachs. They included benthic species such as *Psettichthys melanostictus* and *Agonus acipenserinus,* as well as fishes of the pelagic families of Clupeidae, Osmeridae, and Myctophidae.

Feeding by *S. flavidus* on animals after both are caught in the net (net feeding) is not thought to be a serious source of error because (i) the major prey, euphausiids, are too small to be retained by the nets and (ii) fishes that were found in the stomachs were often well-digested, indicating that they were not recently ingested.

Although data are limited, the weight of stomach contents as a proportion of fish weight suggests that feeding may have been more intense at night (2100–2400 h) than during the day in the Queen Charlotte Sound. The proportion of stomach: fish weights for fish in each of the three nighttime trawls was higher than in any of the daytime trawls; median stomach fullness was also higher in fish caught at night (Table 1). Off Washington, trends were less clear. Stomach weight per fish weight was usually higher from night than day tows and was highest for fish caught early in the morning (0735–0755 h), when stomach fullness also was highest. The proportion of stomach contents that were well-digested and fresh were not markedly different between day and night at either location.

TABLE 1. Summary of Collection and Feeding Habits Data for *S. flavidus* During 18–20 April 1977 for the Coast of Washington and 23–26 September 1976 for Queen Charlotte Sound, British Columbia.

Time (hours)	Day (D) or Night (N)	Location	No. fish stomachs examined	Mean fish length (FL) (cm)	Median stomach fullness	Median stage of digestion	Mean wet wt. of stomach contents	Mean No. prey taxa per fish	Mean No. prey individuals per fish	Avg. wt. of stomach contents as % of fish wt.
WASHINGTON COAST										
0404–0428	N	48° 04.5′N 125° 35.5′W	24	46.8	1	2	2.6	2.4	17.7	0.2
0822-0857	D	48° 04.7′N 125° 35.8′W	7	48.3	1	2	2.0	2.9	12.1	0.1
0101–0131	N	48° 04.5′N 125° 35.9′W	20	46.5	2	2	6.2	2.6	53.8	0.5
0735–0755	D	48° 10.0′N 125° 39.2′W	24	46.0	3	1	16.1	3.1	155.7	1.1
0154–0224	N	48° 04.9′N 125° 35.7′W	9	47.3	1	2	4.2	2.4	26.5	0.3
0506–0536	N	48° 10.0′N 125° 39.2′W	21	47.1	1	2	7.7	2.5	59.9	0.5
1331–1401	D	48° 05.1′N 125° 35.9′W	9	46.8	2	2	3.6	2.7	38.9	0.2
QUEEN CHARLOTTE SOUND										
1800–1900	D	51° 29.2′N 128° 50.6′W	8	48.5	0	1	2.2	0.9	25.3	0.1
1441–1455	D	51° 29.2′N 128° 42.0′W	2	—	1	1	4.3	1.0	1.0	0.2
1710–1748	D	51° 28.0′N 128° 43.0′W	26	49.0	1	2	5.3	1.7	24.6	0.3
2118–2233	N	51° 28.0′N 128° 43.0′W	20	49.0	2	2	9.3	2.1	22.5	0.6
1149–1225	D	51° 29.7′N 128° 40.6′W	20	46.1	1	1	2.7	2.0	10.8	0.1
1857–2320	N	51° 29.0′N 128° 42.0′W	10	47.8	2	2	8.4	1.0	7.6	0.5
2158–2341	N	51° 27.0′N	10	48.8	2	1	10.0	2.7	45.4	0.5

TABLE 2. Percent Frequency of Occurrence of Identified Prey Taxa From Two Areas of Capture of *Sebastes flavidus*.

Taxa	Frequency of Occurrence (%)[1] Washington area	Queen Charlotte sound
Crustacea		
Thysanoessa spinifera	86	74
Euphausia pacifica	87	35
Euphausiacea	75	36
Pasiphaea pacifica	3	1
Pandalus jordani	—	6
Mysidae	—	1
Primno macropa	1	—
Vibilia sp.	—	3
Parathemisto pacifica	—	1
Copepoda	—	1
Isopoda	1	—
Fishes		
Hemilepidotus sp.	1	—
Psettichthys melanostictus	—	1
Agonus acipenserinus	—	1
Thaleichthys pacificus	—	2
Clupea pallasi	—	1
Stenobrachius leucopsarus	—	5
Clupeidae	—	9
Osmeridae	—	1
Polychaeta		
Glycinde picta	3	—
Cephalopoda		
Octopoda	2	—
Coelenterata	—	1
Number of stomachs	114	96

[1] Frequency of occurrence based on fish containing food.

DISCUSSION

Our findings indicate that *S. flavidus* off Washington fed almost exclusively on euphausiids, whereas in Queen Charlotte Sound they fed on euphausiids as well as a variety of fishes. Benthic animals were found in stomachs at both locations, but were more common in fish from Queen Charlotte Sound where agonids and pleuronectids were also important. Based on our limited sampling, both geographically and temporally, *S. flavidus* apparently feeds mainly on pelagic animals but is an opportunist, occasionally eating benthic animals as well.

The absence of the lanternfish, *Stenobrachius leucopsarus,* in the diet off Washington supports the idea of Pereyra, Pearcy, and Carvey (1969) that this mesopelagic species, which dominated the diet of *S. flavidus* south of the Astoria Canyon, was advected into shallow water from nearby deep canyon waters. Because lanternfishes are generally absent or rare in coastal waters (Pearcy 1964, 1977), they are probably available as important prey only near submarine canyons or the continental slope. A few *S. leucopsarus* were found in rockfish stomachs from Queen Charlotte Sound where tows were made in deeper water than off Washington, close to the 200 m contour and slope waters.

One of the objectives of this study was to learn if *S. flavidus* exhibited diel periodicity in feeding. Our results, though admittedly meager, suggest that the rockfish had fullest stomachs at night or early morning. But fresh, undigested food items were found in fish collected during day and night periods in both regions, suggesting some feeding during both day and night periods.

Other research indicates that rockfishes may feed during day and/or night. Based on the presence of full stomachs of relatively undigested prey, Pereyra *et al.* (1969) concluded that *S. flavidus* near the Astoria Canyon fed during the day. Several species of *Sebastes* were also found to have full stomachs of fish prey in Monterey Bay during the day (Sepulveda-Vidal 1977). Based on underwater observations of behavior and feeding habits, Ebeling and Bray (1977) and Hobson and Chess (1976) concluded that the shallow-water, kelp-dwelling rockfishes *S. carnatus, S. chrysomelas, S. atrovirens,* and large juvenile *S. serranoides* are predominantly noctural feeders in California waters.

Euphausiids are common prey for several species of rockfishes inhabiting deeper waters of the continental shelf (Moiseev and Paraketsov 1961, Phillips 1964, Snytko and Fadeev 1974, Carlson and Haight 1976). *E. pacifica* and *T. spinifera,* abundant euphausiids along the west coast, are known to undertake diel vertical migrations (Brinton 1967, Alton and Blackburn 1972, Youngbluth 1976). Hence they would be most concentrated near the sea floor in coastal areas during the day and in surface waters at night. Rockfishes feeding on euphausiids, or other vertically migrating prey, may have similar diel vertical movements and reside closer to the sea floor by day than night. This behavior would maximize availability of diel-migrating prey. It would also affect susceptibility of fish to capture in trawls towed along the bottom. This may explain the larger catches of some rockfishes in bottom trawls during the day that the night (Westrheim 1970, Sepulveda-Vidal 1977). Based on logbook data from otter trawl catches of *S. flavidus* off the central coast of Washington, Fraidenburg, Lemberg, and Kimura (1979) found that time of day significantly influenced catch rates, with highest catches generally during daylight periods. They reported a day-night difference in catch rates of *S. entomalus,* but not *S. flavidus,* in their research trawling off northern Washington, however.

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DISTRIBUTIONAL ECOLOGY OF NATIVE AND INTRODUCED FISHES OF THE PIT RIVER SYSTEM, NORTHEASTERN CALIFORNIA, WITH NOTES ON THE MODOC SUCKER[1]

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Fish populations in Pit River and its tributaries between Turner and Juniper creeks were surveyed during summer and fall 1978. The native Sacramento sucker, *Catostomus occidentalis;* Sacramento squawfish, *Ptychocheilus grandis;* hardhead, *Mylopharodon conocephalus,* association was found in the undisturbed upper reaches of Pit River. Introduced species such as golden shiner, *Notemigonus crysoleucas;* bluegill, *Lepomis macrochirus;* and largemouth bass, *Micropterus salmoides,* dominated the lower river catch, where the habitat had been altered by man's activities. Tributaries were dominated by Sacramento suckers and squawfish. Catostomids that were classified as Sacramento sucker—Modoc sucker, *Catostomus microps,* hybrids were captured within Pit River and Willow Creek, which suggests that the rare Modoc sucker was found there within the not too distant past.

INTRODUCTION

Pit River of northeastern California supports a variety of native fishes common to the Sacramento-San Joaquin system and a number of introduced species. Also found within the drainage are two endemic species, the Modoc sucker and the rough sculpin, *Cottus asperrimus,* both classified as rare by the California Fish and Game Commission (Fisk 1972; Leach, Brode, and Nicola 1974). In addition, the Modoc sucker has been classified as endangered by the American Fisheries Society Endangered Species Committee (Deacon *et al.* 1979). As a result of the presence of these rare species the majority of ichthyological study on the Pit River system has concentrated around their status and a lack of documentation exists for the remainder of the drainage. Rutter (1908) was the first to describe the original fish fauna present in the Sacramento and San Joaquin River Basins. Distribution, morphology, and life history information on the Modoc sucker has been collected by a number of investigators (Martin 1967, 1972; Moyle 1974; Moyle and Marciochi 1975; Ford 1977; and Boccone and Mills 1979). The effects of channelization on the aquatic biota of a section of Rush Creek was presented by Moyle (1976*a*). Daniels and Moyle (1978) reported on the biology, distribution, and status of the rough sculpin in lower Pit River, lower Hat Creek, and Fall River.

Data presented in this paper were collected in coordination with a larger study conducted by the Bioresources Center of the Desert Research Institute for the U.S. Bureau of Reclamation. The primary objective of the study was to determine if the proposed Allen Camp Reservoir, to be constructed on Pit River as part of the Central Valley Project, would be detrimental to habitat occupied by either the Modoc sucker or the rough sculpin.

[1] Accepted for publication October 1981.

STUDY AREA

The general region of study is approximately 100 km northeast of Redding and 40 to 50 km southwest of Alturas in southwestern Modoc and northwestern Lassen counties. The specific study area includes that portion of Pit River and its tributaries between Turner Creek to the north and Juniper Creek to the south. Ash Creek from Adin to its confluence with Pit River and Willow Creek were also included within the project boundary (Figure 1).

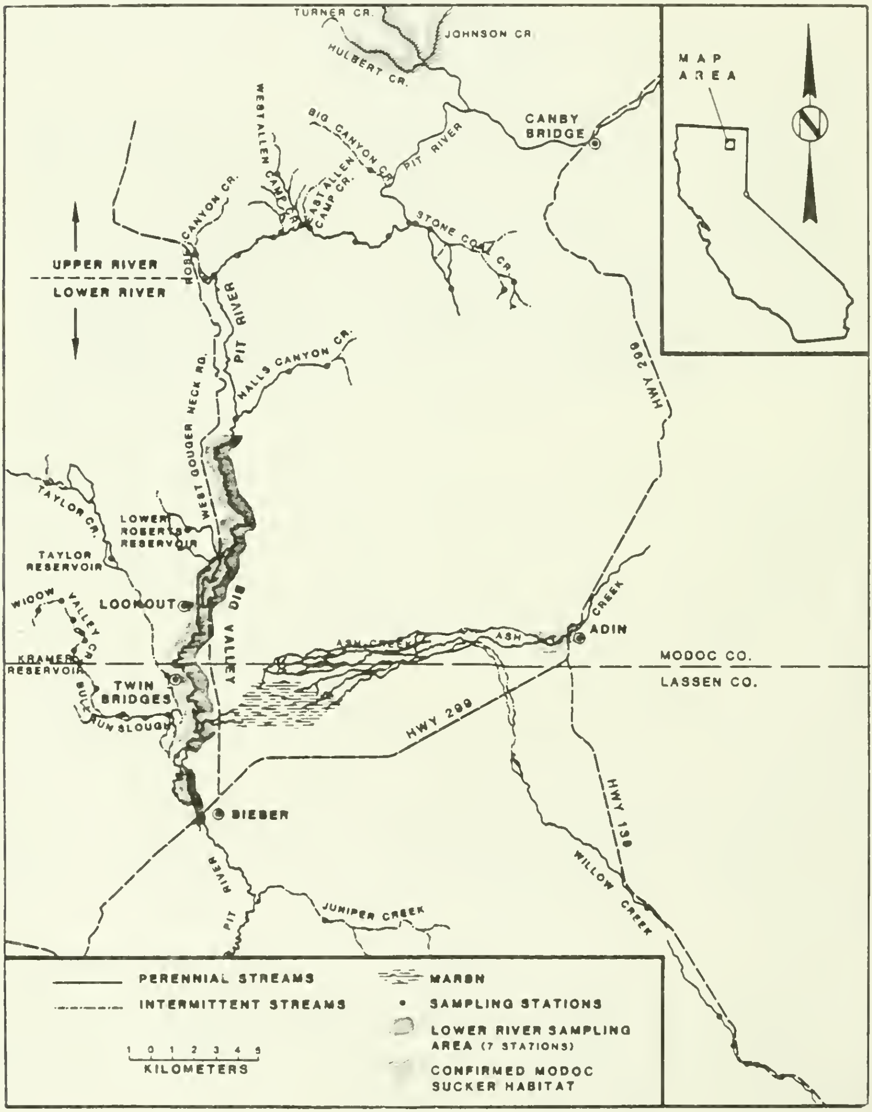

FIGURE 1. Location map of Pit River Study area, Lassen and Modoc counties, California.

Pit River has a total drainage basin of approximately 13,468 km², originating in the Warner Mountains of extreme northeastern California and flowing southwest to Shasta Reservoir (U.S. Geological Survey 1977). Of the total drainage basin, roughly 38% (5,050 km²) is upstream from the study area.

The upper river portion of the survey area, specifically the reach between Big Canyon Creek and Rose Canyon Creek, flows through a relatively narrow valley, which would provide the basin for the proposed Allen Camp Reservoir. This section of river is bordered with willow (*Salix* sp.) in many instances and tall grasses provide a meadow appearance in the flood plain area. Transition from grasses to shrubs, such as big sagebrush, *Artemesia tridentata;* rabbitbrush, *Chrysothamnus* sp.; bitterbrush, *Purshia tridentata,* interspersed with such species as cheatgrass, *Bromus tectorum;* lupine, *Lupinus* sp.; and tumblemustard, *Sisymbruim altissimum,* occurs with a slight increase in elevation from the plain. Utah Juniper, *Juniperus osteosperma;* ponderosa pine, *Pinus ponderosa;* Jeffrey Pine, *Pinus jeffreyi;* and an occasional oak, *Quercus* sp., are sparsely distributed in the lower foothills bordering the river. The elevation of the valley floor for the upper river is approximately 1,280 m with the surrounding mountains rising to heights in excess of 1,829 m.

Pit River enters Big Valley from the north through a deep canyon just south of Rose Canyon Creek. Big Valley lies at an elevation of approximately 1,265 m, is nearly 20.8 km long and 24 km wide, with the topography generally flat to moderately rolling. The river flows in a southerly direction, meandering through the valley, diverging and converging in a series of sloughs that drain many of the agricultural return flows along its course. This section of river will be referred to in this paper as the lower river. Ash Creek, a main tributary to Pit River, enters Big Valley at its eastern edge at Adin. The creek flows west spreading over a large marshy area known as Big Swamp and eventually joins Pit River just north of the town of Bieber. Both Pit River and Ash Creek within Big Valley are bordered along the majority of their reach with dense willow stands that are surrounded immediately by either native grasses or agricultural lands. Most of the agricultural endeavors in the valley are in private ownership and nonintensive in nature, with some grains and alfalfa occasionally grown.

Willow Creek was a major tributary surveyed and enters the southeast corner of Big Valley, eventually feeding Ash Creek approximately 4 km west of Adin. Other major tributaries surveyed that had substantial flow included the Widow Valley Creek system, Taylor, Halls Canyon, and Stone Coal creeks. Tributaries sampled that are generally intermittent, but were flowing during spring runoff, included Juniper, Rose Canyon, East and West Allen Camp, and Big Canyon creeks. Kramer, Taylor, and Lower Roberts reservoirs were also surveyed.

METHODS AND MATERIALS

Sampling of tributary streams was conducted by a two-man team from 17 May through 7 June, 1978. The majority of the tributary fish collections were made using a Coffelt Model BP-2 backpack electrofishing unit. Sections of tributaries 50 m in length were blocked with nets and systematically sampled in three successive runs. Random sampling with the backpack electrofishing unit was conducted in many instances to verify the existence of a fish population and to quickly survey large portions of stream habitat.

Pit River was sampled during three segments of summer and early fall 1978: 10 July–15 July; 22 August–25 August; and 16 October–21 October. Sections of the river deeper than 1 m were sampled with gill nets and an electrofishing boat provided by the California Department of Fish and Game. Nylon multi- and single-paneled gill nets 2 m deep and 35 m long with meshes of 3.8, 5.1, 6.4, 6.6, 8.9, and 10.2 cm stretched measure were used most extensively. A 15.2-m, small mesh (0.25 cm) beach seine was utilized.

Fish collections at shallow river stations were conducted with the use of an Onan 120 v AC generator transported on a 2-m johnboat with electrical current transferred to the water via two negative and two positive hand-held electrodes that were effective to a width of 18 m. Stream sections 200 m in length were blocked from bank to bank with screen supported by steel fence posts that were driven into the river channel. The sections were then sampled in three successive and identical runs.

A total of 52 stations was sampled; 13 were on Pit River and 39 on tributaries. At each station the number of fish collected was recorded by species. Fish were weighed to the nearest gram and fork length measurements recorded to the nearest millimeter. Stream depth, width, percent substrate type (boulder-gravel-mud), percent pool and riffle abundance, percent shade, elevation, and temperature were also recorded at each station. Discharge measurements were taken using a calibrated pygmy flow meter.

Statistical data analysis including correlation coefficients and discriminant analysis were conducted utilizing the Tustat-II statistical package (Koh 1973). Coefficient correlations were calculated by Spearman's rho (denoted r_s), which requires the use of ordinal rankings rather than the absolute value of variables. Rank correlation was deemed more appropriate because it eliminates the variable of size of habitat which is directly related to the absolute numbers of fish caught. The use of this method does not require meeting the assumptions of parametric analysis such as a normal distribution or the metric quality of interval scale. A Student's *t* statistic was used in calculating the probability associated with null hypotheses formulated to detect significant differences in fish catch statistics by species and area. Arcsine transformations were utilized to normalize fish catch data and meet the assumptions of parametric statistical analyses. Discriminant analysis is a technique used in numerical taxonomy to test a series of characteristics of different populations to analytically separate them into discrete groups, and subsequently test which group an unknown specimen fits into (Sokal and Rohlf 1969). This method was used quantitatively to separate Sacramento, hybrid, and Modoc suckers.

RESULTS AND DISCUSSION

PIT RIVER

A total of 2,221 fish comprising 14 species, 11 genera, and six families was captured from stations on the Pit River system within the survey boundary (Table 1). The largest group represented in the river was the cyprinid family, from which five species were collected. Native and introduced fishes were both represented by seven species. Sacramento sucker, hardhead, and Sacramento squawfish were the dominant species. Less abundant species with relatively high populations included golden shiner; largemouth bass; channel catfish, *Ictalurus punctatus*; and green sunfish, *L. cyanellus*. Introduced species composed 38.5% of the total river sample.

TABLE 1. List of Fish Species, Total Number and Percent Composition by Species, and Number of Stations at Which a Specific Species was Captured for Pit River and Tributary Stations Between Turner Creek and Juniper Creek, California.

		Pit River stations			Tributary stations		
Common name	*Scientific name*	*Number captured*	*Percent composition*	*Frequency of occurrence by station*	*Number captured*	*Percent composition*	*Frequency of occurrence by station*
Sacramento sucker	*Catostomus occidentalis*	613	27.6	11	162	18.1	15
Sacramento squawfish	*Ptychocheilus grandis*	281	12.7	12	165	18.4	14
Hardhead	*Mylopharodon conocephalus*	461	20.8	8	8	.9	2
Channel catfish [1]	*Ictalurus punctatus*	175	7.9	11	–	–	–
Largemouth bass [1]	*Micropterus salmoides*	190	8.6	11	41	4.6	1
Green sunfish [1]	*Lepomis cyanellus*	134	6.0	10	24	2.7	5
Golden shiner [1]	*Notemigonus crysoleucas*	218	9.8	5	51	5.7	2
Speckled dace	*Rhinichthys osculus*	1	.04	1	161	18.0	5
Bluegill [1]	*Lepomis macrochirus*	95	4.3	10	38	4.2	1
Brown bullhead [1]	*Ictalurus nebulosus*	40	1.8	11	162	18.1	7
Tui chub	*Gila bicolor*	3	.1	1	25	2.8	1
Sunfish [1]	*Lepomis sp.*	3	.1	2	16	1.8	8
Pit-Klamath brook lamprey	*Lampetra lethophaga*	1	.04	1	–	–	–
Hybrid sucker	*Catostomus sp.*	2	.09	1	3	.3	2
Pit sculpin	*Cottus pitensis*	4	.2	2	26	2.9	6
Rainbow trout	*Salmo gairdneri*	–	–	–	13	1.5	3

[1] Introduced Species

Seven species of fish were widely distributed within the river, occurring at between 10 and 12 of the 13 stations surveyed. The most widely distributed was the Sacramento squawfish, which was found at 12 sites, followed by Sacramento sucker, channel catfish, largemouth bass, and brown bullhead, *I. nebulosus,* found at 11 locations. Green sunfish and bluegill, also far ranging, were collected at 10 of the survey sites. Of the seven most widely distributed species, five are not native to the Pit River system.

The upper and lower Pit River stations can be divided into two habitat types with distinct fish associations. The upper reach between Turner Creek and Rose Canyon Creek is probably similar to the way it was historically. With the exception of cattle grazing and farming activity presently occurring along its course, man has not impounded or appreciably disturbed the river. The upper reach is characterized by a relatively steep gradient and subsequent high stream velocities with riffle, run, and pool habitats present. Substrate type is primarily boulders and gravel with sand and silt less prevalent. The proposed Allen Camp Reservoir will inundate a large portion of this section of Pit River.

In contrast, the lower Pit River stations between Rose Canyon and Juniper creeks are generally characterized by sluggish flows created by only a slight gradient or impounded water behind irrigation diversions in Big Valley. Substrate is usually silty, water depth is greater than 1 m, turbidity is moderate (Secchi disc reading of 0.7 m), water temperatures are relatively high when compared to flowing sections, and the velocity of stream flow is generally negligible. To give an example of a typical diversion dam on lower Pit River, the Gerig Diversion is approximately 4m high, but backs up water to Lookout, a small town approximately 12 river km to the north. Within 0.4 km to the north of Lookout is the Lookout Diversion which again backs Pit River water at least to the confluence with Halls Canyon Creek, a distance of over 16 river km.

The group of fish species found in the upper Pit River is reflected by stream conditions judged conducive to native fishes. The Sacramento sucker-Sacramento squawfish-hardhead association made up 72.5% of the catch for this reach of stream. These native species were positively correlated ($P < .05$) with the presence of one another and negatively correlated with introduced exotics (Table 2). Other fishes found with this association included channel catfish, which dominated one station's biomass, Pit sculpin, *Cottus pitensis;* speckled dace, *Rhinichthys osculus;* Pit-Klamath brook lamprey, *Lampetra lethophaga;* green sunfish; largemouth bass; bluegill; and brown bullhead.

Moyle (1976*b*) states that the sucker-hardhead-squawfish zone is a common native fish association of the Sacramento and San Joaquin drainages. He describes the zone as having average summer flows of 300 liters/s or more, deep rocky pools and wide, shallow riffles. Summer water temperatures of the zone typically exceed 20° C and may fluctuate widely with air temperatures. The altitudinal range of the zone is limited from 27 to 450 m above sea level in the San Joaquin drainage, but the association appears to inhabit a much wider range in tributaries to the Sacramento River. This description, in many ways, is similar to that found at the upper Pit River stations. Large fluctuations in discharge have ranged from 13,000 cfs (March 1904) to 0.1 cfs (April, August, and September 1943), at Canby (USGS 1977). Water temperature has been recorded as low as 0.0° C (many days during many years) and as high as 31.0° C (June 1973), also

TABLE 2. Rank Correlation Matrix for the 10 Most Abundant Fish Species Collected from the Pit River and Eight Most Abundant Fish Species Collected from Tributaries Between Turner Creek and Juniper Creek, California. [1]

Pit River	*Sacramento sucker*	*Sacramento squawfish*	*Hardhead*	*Channel catfish*	*Largemouth bass*	*Green sunfish*	*Golden shiner*	*Bluegill*	*Brown bullhead*	*Pit sculpin*
Sacramento sucker										
Sacramento squawfish	.63									
Hardhead	.69	.66								
Channel catfish			.67							
Largemouth bass		−.53	−.53							
Green sunfish	.67	.66	.59	.48						
Golden shiner		−.51	−.69	−.48	.78					
Bluegill		−.47			.71		.55			
Brown bullhead						−.42				
Pit sculpin				.62		.62			−.54	

Tributaries	*Sacramento sucker*	*Sacramento squawfish*	*Green sunfish*	*Speckled dace*	*Brown bullhead*	*Hybrid sucker*	*Pit sculpin*	*Rainbow trout*
Sacramento sucker								
Sacramento squawfish	.61							
Green sunfish		.40						
Speckled dace	−.32							
Brown bullhead			.40					
Hybrid sucker	.41							
Pit sculpin	.45			−.28	−.34	.61		
Rainbow trout						.76	.42	

[1] Data shown are significant at the 95% confidence level ($P < .05$)

at Canby. The elevation of the general area is approximately 1,272 m above sea level and the physical habitat is similar to that described by Moyle (1976*b*). Organisms inhabiting this environment must tolerate a wide range of environmental variables.

Native species did not exhibit a significant preference for a habitat (Table 3). These non-significant relationships are undoubtedly masked by the fact that native species can adapt to a number of environmental conditions as was evidenced by their dominance in the tributary catch and presence in the lower river catch. Exceptions to this were the hardhead whose presence was positively correlated with flow ($P < .05$) and boulder substrate ($P < .05$), and squawfish which preferred an environment with riffles present ($P < .05$). With the exception of channel catfish, introduced species did not make up a significant portion of the upper river catch.

The Sacramento sucker had the greatest biomass with a mean of 64.2% of total fish weight for stations on the upper river reach. Channel catfish had a mean biomass of 23.6% per station, providing a significant and apparently underutilized sport fishery (V. King, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.).

Diversity averaged 8.2 species per upper river station ranging from 8 to 9 species per site. Species most infrequently captured were Pit sculpin (2 stations), speckled dace (1 station) and lamprey (1 station).

Specimens classified as Sacramento-Modoc sucker hybrids, using a stepwise discriminant function analysis, were found inhabiting sections of the upper river near the Miller Ranch and the headwaters of Willow Creek. Meristic characters selected as variables for this analysis included number of scales along the lateral line, number of dorsal rays, standardized eye diameter, and scale rows above and below the lateral line (Table 4). The Sacramento sucker and hybrid suckers were collected during this study; Modoc suckers were collected from Hulbert Creek (U.C. Davis collection).

Results from discriminant function analysis indicate that significant discriminating power was achieved with the characters used. Of the five characters, those with the most power to differentiate taxons were lateral line scales, dorsal fin rays, and standardized eye diameter, all of which were significantly different at the group level ($P < .001$). Based on three specimens collected from Rush Creek, Modoc County in 1898, Rutter taxonomically separated the Modoc sucker from the Sacramento sucker by eye diameter, head size and shape, scale size, and differences in the fontanelle (Rutter 1908). The standardized eye diameter for Modoc sucker specimens utilized during this study (Hulbert Creek population) fell between the range documented by other investigators (Martin 1972, Ford 1977). However, Sacramento sucker specimens collected during this study had a slightly smaller standardized eye diameter than the Modoc sucker.

The most convenient method of interpretation of discriminant analysis is a graphical display of each group and their centroids (Figure 2). Definite differences in groups and centroids were achieved with the two discriminating functions derived from the characters used in the analysis. Further support of the effectiveness of the discriminating variables is that of all the cases used in the analysis only 8.2% were predicted to be misclassified.

TABLE 3. Rank Correlation Matrix Showing the Relationship Between Fish and 12 Habitat Characteristics Measured at 13 Pit River and 23 Tributary Stations Between Turner Creek and Juniper Creek, California. [1]

	Habitat Characteristics												
Fish Species	*Flow (l/sec)*	*Temperature (°C)*	*Elevation (m)*	*Average Depth (m)*	*Maximum Depth (m)*	*Width (m)*	*Pool (%)*	*Riffles (%)*	*Shade (%)*	*Boulders (%)*	*Gravel (%)*	*Mud (%)*	*(%)*
Sacramento sucker						−.43*							
Sacramento squawfish						−.41*		.40*					
Hardhead	.33*									.31*			
Channel catfish						−.39*							
Largemouth bass		.38*	−.41*	.52**	.53**	−.45**	.39*				−.45**	.35*	
Green sunfish				.43**	.44**	−.39*					−.31*		
Golden shiner	−.55**	.47**	−.65**	.55**	.52**		.64**	−.51**	−.36*	−.40*	−.55**	.64*	
Speckled dace		−.33*		−.46**	−.36*		−.34*			.31*			
Bluegill		.34*	−.38*	.44**	.50**	−.32*	.33*	−.39*			−.36*	.31*	
Brown bullhead	−.37*		−.50**			−.37*					−.36*	.32*	
Tui chub	−.33*		−.38*	.36*	.37*		.32*	−.34*					
Sunfish sp.			−.42**							−.41*		.34*	
Pit-Klamath brook lamprey													
Hybrid sucker	.30*	.31*	.34*										
Pit sculpin											.31*	−.44*	
Rainbow trout			.42**						.31*		.34*	−.30*	

[1] * 95% confidence level P < .05; ** 99% confidence level P < .01.

TABLE 4. Meristic Data for Six Characters Utilized in Stepwise Discriminant Analysis for the Sacramento Sucker, Hybrid Sucker and Modoc Sucker.

	Scales in lateral line	*Dorsal rays*	*Standardized eye diameter*	*Scales above lateral line*	*Scales below lateral line*
Sacramento sucker (n=89)*:					
mean	71.6	12.3	0.043	14.7	12.7
standard deviation	4.2	0.65	0.009	1.29	1.90
Hybrid sucker (n=5)**:					
mean	81.0	11.6	0.042	16.2	13.2
standard deviation	2.9	0.55	0.005	1.30	1.30
Modoc sucker (n=7)***:					
mean	84.6	10.6	0.049	16.4	13.3
standard deviation	1.62	0.53	0.003	1.13	1.25

* Collected from various stations within project area
** Collected from Willow Creek and upper Pit River
*** Collected from Hulbert Creek (U.C. Davis Collection)

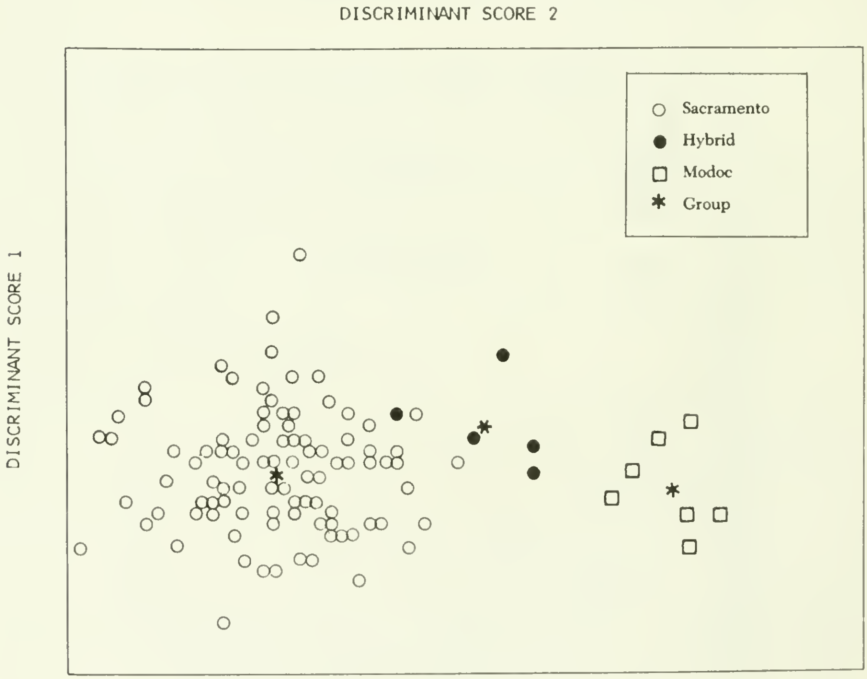

FIGURE 2. Stepwise discriminant analysis plot of five meristic characters for Sacramento suckers (○), hybrid suckers (●), and Modoc suckers (□) (* indicates a group centroid).

The presence of hybrid suckers in the river suggests that either Modoc suckers recently inhabited the upper river or that the gene pool has been influenced by migrating individuals from Turner Creek, a tributary known to support the sucker only 8 km upstream.

The lower section of Pit River, which has been altered by human activities, was preferred by many of the introduced species. This disruption of the river has created habitat not preferred by native species (Table 3), but is ecologically similar to the natural streams and lakes of introduced species. Dominant fishes found in this reach were of the golden shiner-bluegill-largemouth bass association which comprised 61.9% of the total fish captured at seven lower river stations. Any one of these species was positively correlated with the presence of the other two ($P < .05$). Golden shiner was the dominant fish captured at three of the seven lower river stations. The only native fish that made up the majority of the catch in this reach was the Sacramento squawfish. Other species found in lesser abundance included tui chub, *Gila bicolor,* brown bullhead, green sunfish, channel catfish, Sacramento sucker, and hardhead. Golden shiner, largemouth bass, and bluegill showed significant positive correlations for temperature, average and maximum depth, pools, and muddy substrate (Table 3). For at least two of the above species, significant negative correlations were found for elevation, stream width, riffles, and gravel substrate.

Although introduced fishes had higher numerical populations than natives in the lower river they were generally smaller in size and contributed less to total biomass. Sacramento suckers and Sacramento squawfish constituted 60.2% of the biomass within this reach. At one station Sacramento suckers composed 32.7% of the total catch by number ($n = 65$), but 84.3% of the total biomass. Golden shiners at this station composed 37.2% of the catch by number ($n = 74$) but accounted for only 1.4% of the biomass.

Species diversity was usually high on the lower river ranging from six to nine species per station (mean = 8.1). The mean number of introduced species, however, was 5.6 per station, suggesting their habitat preference for the disturbed environment.

To normalize the data and meet parametric assumptions an arcsine transformation (Sokal and Rohlf 1969) was used to run *t*-tests for equality of species associations found at the upper versus lower river stations. A *t*-test was also used to compare percent composition data for these two habitat types. Results of these tests revealed a significantly higher proportion of the shiner-bluegill-bass association in the lower river than all other species found in that habitat ($P < .001$). Likewise, the sucker-squawfish-hardhead association in the upper river was highly significant ($P < .001$).

Tributaries

Fish captured in the tributaries totaled 895 individuals, representing 13 species, 11 genera, and six families. From this total, seven species are native to the system and six are introduced. The largest group represented was the cyprinid family from which five species were collected. Fish were present at 23 (59%) of the tributary stations surveyed and absent at the remaining 16. Sacramento squawfish, Sacramento suckers, brown bullhead, and speckled dace dominated the tributary catch (Table 1). Of lesser importance were golden shiner, largemouth bass, and Pit sculpin.

The Sacramento sucker was the most widely distributed species occurring at 15 (65.2%) of the stations where fish were captured, closely followed by Sacramento squawfish at 14 (60.8%). Introduced fishes made up only 37.1%

of the total tributary sample, but occurred at 11 (47.8%) of the 23 stations at which fish were present. Sacramento suckers and Sacramento squawfish were dominant at 12 (52.2%) locations, each having the most individual representatives at six stations. On the average, suckers made up 38.4% of the total sample at stations where they were present. The two species made up 64.8% of collections where found together. Of the total tributary stations at which fish were captured, only five failed to have either suckers or squawfish present. Other species that dominated station catches included golden shiner (2 stations), brown bullhead (2 stations), Pit sculpin, sunfish, and speckled dace.

The greatest biomass was contributed by suckers and squawfish, the mean weight of the two comprising 72.1% of the total at tributary stations. It must be noted here that numerical dominance by these species may be a function of electrofishing techniques which are more selective for the capture of fish with large body size. Smaller species are more likely to be either unaffected by the electrical field or overlooked during dip netting.

Moyle and Nichols (1974) reported similar results in their study of the squawfish-sucker-hardhead zone of Sierra Nevada foothill streams. They found Sacramento sucker and Sacramento squawfish to be the most abundant fishes within the zone with suckers occurring in 42% and squawfish in 38% of 130 sampling sites.

Reservoirs on tributaries surveyed were primarily inhabited by introduced species preferring lentic habitats. The catch at Taylor Reservoir (Figure 1) was dominated by brown bullhead and largemouth bass, the two composing 87.0% of the total. Lower Roberts Reservoir, a highly turbid water storage impoundment, was dominated by golden shiner and bluegill with smaller populations of green sunfish, tui chub, and brown bullhead. Sacramento suckers and squawfish were captured by gill netting at Kramer Reservoir.

Disregarding streams sampled at the confluence with Pit River, those with the highest species diversity were within the Willow Creek drainage (mean = 3.3) followed by the Widow Valley Creek drainage (mean = 3.2). Diversity in tributary streams was found to be positively correlated with stream discharge at the time of sampling ($P < .05$). Mean diversity for tributary stations was significantly less than that for Pit River stations ($P < .001$). The higher diversity and lesser variation for the river is likely a reflection of the more stable environmental conditions experienced at these habitats. With the exception of the Willow and Widow Valley creek drainages the majority of streams feeding Pit River within this area are primarily utilized during the spring runoff period as short-term nursery habitat for species requiring or preferring the lotic environment for spawning. In as much as suckers and squawfish are both stream spawning species (Burns 1966, Moyle 1976*b*), juveniles dominated the catch at most stations. Many streams in which fish were present in the spring were dry by mid-summer with the exception of an occasional pool. This observation is consistent with Boccone and Mills (1979) who found Modoc sucker populations in Turner and Johnson creeks utilizing intermittent tributaries during the spawning seasons.

In tributaries, the most common species association was that of the Sacramento sucker and Sacramento squawfish. These species inhabit the same regions; suckers preferring the bottom and feeding on algae and detritus and small squawfish inhabiting mid and surface areas feeding primarily on terrestrial and aquatic insects (Burns 1966, Moyle 1976*b*). Other species positively correlated with the presence of suckers included hybrid suckers and Pit sculpin, but a negative correlation was found between suckers and speckled dace (Table 2). Sunfish appeared not to prefer areas inhabited by squawfish.

Dominant introduced species in tributaries were green sunfish and brown bullhead. At least one of these species occurred at seven of the 24 (29.2%) tributary stations sampled and both were found at five of these seven stations. Green sunfish preferred areas not inhabited by squawfish, and brown bullhead were never found with Pit sculpin (Table 2).

Game fishes were poorly represented in tributaries and the only significant fishery was supported by a small rainbow trout, *Salmo gairdneri,* population found near the headwaters of Halls Canyon Creek. This was the only species captured in this tributary and the habitat could potentially be an excellent site for the eventual transplant of the Modoc sucker.

Suckers possessing meristic characters that classified them as hybrids between Sacramento and Modoc suckers were found in Willow Creek at two sites. Ford (1977) mentions capturing Modoc suckers in Willow Creek from three isolated pools approximately 27 km upstream from Ash Creek. These specimens were later classified as hybrids (T. Mills, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.). The habitat at Willow Creek is nearly identical to habitat preferred by the Modoc sucker as described by Moyle and Marciochi (1975). Historically, the stream may have been inhabited by the Modoc sucker but has recently been invaded by the Sacramento sucker. Considering the high fecundity and promiscuity common to suckers, introgression would take a relatively short time within an isolated population.

SUMMARY AND CONCLUSIONS

Of the 14 native and 12 introduced fishes described by Moyle (1976*b*) as inhabiting the Pit River system eight native and seven introduced species were identified during this study. Daniels and Moyle (1978) in their report on the rough sculpin in the lower Pit River—Fall River systems identified 12 species (10 native) associated with their study organism. Eight of these were captured in the current study.

The unique native fish associations of the Sacramento-San Joaquin River systems have in many instances been replaced by introduced exotics as shown by this survey and others. Streams of the Sierra Nevada foothills above the San Joaquin Valley were surveyed between 1969 and 1971 (Moyle and Nichols 1974). Compared to pre-1900 distributions, introduced species had expanded their ranges and representative populations of native fishes were restricted to a relatively narrow elevational range. Introduced associations were found at low elevations in intermittent streams that had been modified by man. In a similar study Aceituno, Caywood, and Nicola (1976), in a fish survey of Coyote Creek below Anderson Reservoir, found that the stream had lost over half of its native fish populations since being studied by Snyder (1905). With man's increasing population a greater demand will be placed upon water resources in the future and the native aquatic environment will most likely be neglected. At the present time a great deal of emphasis is placed on endangered or threatened species when an impact on the environment is expected. Consideration snould be given to native fish assemblages during analysis of environmental impact as their ecological and evolutionary values are irreparable following aquatic degradation.

Also, of significance was the absence of the Modoc sucker from habitats surveyed during this study. If this species was inhabiting the surveyed upper portions of Pit River it would most likely have been found, as the confirmed Modoc sucker habitats are within the immediate vicinity. The presence of Modoc-Sacramento sucker hybrids suggests that the Modoc sucker occupied at least a portion of Pit River and Willow Creek within the not too distant past. This is consistent with Moyle's (1976*b*) hypothesis proposing that the Modoc sucker has been driven to a smaller population by the relatively recent invasion of fishes (i.e. Sacramento sucker) from the Sacramento-San Joaquin system. It is, therefore, the opinion of this investigator that the Modoc sucker should continue to be classified as rare by the State of California and steps should be taken to have the species federally listed. Consideration should be given to transplanting the species from genetically pure populations to suitable natural habitats such as Halls Canyon Creek and others that could be altered to meet the environmental requirements of the species.

ACKNOWLEDGMENTS

I wish to thank D. Koch, E. Lider, and S. Vigg for their advice and assistance in preparation of the manuscript. P. Moyle from U.C. Davis provided Modoc sucker specimens for taxonomic analysis in addition to valuable consultations during the project. V. King and the California Department of Fish and Game provided field information and an electrofishing boat. Thanks also go to J. Wolski, G. Scoppettone, and R. Bailey for their assistance with the field work and R. Armstrong and S. Cooper for typing several revisions of the paper.

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NOTES

RESULTS OF MOHAVE CHUB, *GILA BICOLOR MOHAVENSIS,* RELOCATIONS IN CALIFORNIA AND NEVADA

The Mohave chub, listed as an endangered species by both the California Fish and Game Commission and the United States Fish and Wildlife Service, is the only known native fish of Mojave River, California (Hubbs and Miller 1943). Undocumented introduction of the arroyo chub, *G. orcutti* (presence noted by Hubbs and Miller in 1934) and the resultant interspecific hybridization and competition, eliminated the Mohave chub as a distinct species from Mojave River by 1967 (Miller 1967). At that time genetically pure Mohave chubs were known to occur only in two ponds (one being Lake Tuendae) and a drainage ditch at Fort Soda, 13 km southwest of Baker, California (Miller 1967). Concern that the Fort Soda habitat would not be adequately maintained, since it required periodic vegetation removal and pumping of inflow water, efforts to move Mohave chubs to other suitable waters were undertaken. Relocation efforts began in 1967 when the United States Bureau of Land Management, in cooperation with the California Department of Fish and Game, introduced fish from Fort Soda into a small pond at Paradise Spa, Nevada (J. Deacon, Professor, University of Nevada, Las Vegas, pers. commun.). In 1969 and 1970 the California Department of Fish and Game introduced Mohave chubs into a total of three California waters (St. Amant and Sasaki 1971). Eight subsequent introductions were made by the Department from 1971 through 1978 (Table 1).

Two of the 12 introductions led to currently established populations. These include populations in Lark Seep Lagoon, near Ridgecrest, and in a pond at the Desert Research Station, near Barstow, both in San Bernardino County. Surveys in 1979 and 1980 showed an abundance of fish in Lark Seep Lagoon, and a recent population estimate indicates that at least 1,650 fish are present in the Desert Research Station pond.

Additionally important to the status of the Mohave chub, the United States Bureau of Land Management has recently adopted a comprehensive habitat management plan for the Fort Soda population. This plan calls for renovation and enlargement of one of the ponds, installation of back-up pumps for filling Lake Tuendae, and control of aquatic vegetation (Bicket 1978).

The status of the Mohave chub is considerably improved as a result of introductions into additional waters. This lack of urgency now allows relocations to be made more selectively and be restricted to the Mojave River drainage. Although the Mohave chub seems to be adaptable to a variety of situations, more information on habitat requirements of the species is needed to evaluate other potential introduction sites.

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J. Deacon (University of Nevada, Las Vegas) furnished current information on Paradise Spa. T. Rado (Bureau of Land Management) provided data on the status of the Barstow Way Station populations. T. McGill (United States Navy) assisted in field work at Lark Seep Lagoon. B. Loudermilk (California Department

TABLE 1. Results of Mohave Chub Relocations in California and Nevada.

Site	County	*Date(s) planted*	*No. of fish planted*	*Date(s) surveyed*	*Population established*	*Cause of failure of introduction*	*Date of reintroduction*	*No. of fish planted*	*Date(s) surveyed*	*Current population*	*Cause of plant failure*
Paradise Spa [1]	—	June 1967	50	April 1981	No	Unknown	—	—	—	No	—
Piute Creek	San Bernardino	18 and 19 December 1969	150	9 November 1976	Yes	—	—	—	1978 and 1980	No	Flood
South Coast Botanic Garden Pond	Los Angeles	27 January 1970	147	—	Yes	Pond drained [2]	20 July 1972; 28 March 1975	55; 105	1976	No	Unknown
Two Hole Springs	San Bernardino	20 August 1970	41	June 1971	No	Unknown	9 July 1971	150	27 July 1971	No	Unknown
Lark Seep Lagoon	San Bernardino	12 July 1971	400	1979 and 1980	Yes	—	5 November 1976	75	1979 and 1980	Yes	—
Dos Palmas Spring Area:											
Dos Palmas Spring	Riverside	25 May 1972	100	8 January 1980	No	Unknown	—	—	—	No	—
Shrimp Pond	Riverside	25 May 1972	100	8 January 1980	No	Unknown	—	—	—	No	—
Lion Country Safari Ponds	Orange	1 June 1972 and 28 March 1975	822	January 1974	Yes	—	—	—	8 November 1977	No	Unknown
Eaton Canyon Nature Center	Los Angeles	5 June 1972	20	—	No	Unknown	—	—	—	No	—
Busch Gardens	Los Angeles	27 July 1972	49	—	No	Unknown	—	—	—	No	—
Barstow Way Station	San Bernardino	22 July 1975	60	16 September 1976; 1979	Yes	Flood	1 July 1981	30	—	Unknown	—
Lake Norconian	Riverside	1978	—	6 February and 3 July 1980	No	Unknown	—	—	—	No	—
Desert Research Station	San Bernardino	12 December 1978	16	Continuous	Yes	—	—	—	—	Yes	—

[1] Located in Clark County, Nevada. All other locations listed are in California.
[2] Fish salvaged and stocked elsewhere.

of Fish and Game) assisted in field work at Piute Creek. K. Sasaki (California Department of Fish and Game) provided valuable assistance in reviewing the manuscript. Special thanks are due to M. Havelka and the Barstow Unified School District for providing habitat and equipment at the Desert Research Station and for their continuing interest in the species.

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COMMON DOLPHINS, *DELPHINUS DELPHIS*, IN MONTEREY BAY

This communication reports what appear to be two of the northernmost sightings of *Delphinus delphis* (common dolphin) in California. Both sightings were made from the R/V SCAMMON of the Center for Coastal Marine Studies, University of California-Santa Cruz.

The first sighting occurred on 1 February 1979 during a random survey of marine birds and mammals in northern Monterey Bay when a pod of 35 to 50 common dolphins was encountered. At 0915 they were first sighted at a distance of 350 to 450 meters in 40 fathoms of water at lat 36° 51′ 40″ N, long 122° 0′ 35″ W, within 6 nautical miles of Santa Cruz wharf. they were moving fairly fast, headed in a southeasterly direction, with several animals repeatedly leaving the water in airborne arcs, with clean reentries.

When approached, 10 to 12 of the larger animals separated from the main group and came to the boat. These animals rode the pressure wave at the bow of the boat, surfed her stern waves, and continued to jump clear of the water. During this time 15 to 20 very direct views of individuals either in the air or very close to the moderately smooth surface were obtained within 10 to 12 meters of my position at the helm. These animals were 2 to 2.5 meters in length. They were dark rust brown above, with amber white sides and ventral surface, and a moderately sharp line of demarcation between colors. Their beaks were definitely, but not prominently, elongated, and the dorsal fins were back-curved and slender.

The other animals remained in a tightly-packed group away from the boat and continued their southeasterly course. Although they remained some distance away, I was able to observe 10 to 15 animals surfacing nearly simultaneously and estimate that some 25 to 40 animals were present in that group. Of these dolphins, 8 to 12 were one-half to two-thirds the size of their close escorts, which appeared to be the same size or only slightly smaller than the animals near the boat. It is likely that the smaller ones were juveniles, (rather than a different species) especially since their dorsal fins resembled those of the larger animals. Some of the smaller animals appeared to be consistently paired with larger ones, surfacing and breathing in tandem with their larger escorts. Surface temperature was 11.6° C.

After 10 min of contact, at a speed of approximately 8 knots, the animals were allowed to proceed unmolested in a SSE direction. When the boat pulled away from a course parallel to that of the main group, the animals around the boat immediately left the boat and returned to the pod. Upon return to shore, identification of the animals as *Delphinus delphis* was confirmed by photographs and descriptions in Leatherwood, *et al.* (1972).

The second sighting occurred exactly one year later, on 1 February 1980, when the SCAMMON encountered 8 or 10 *Delphinus delphis* at lat 36° 52′ 30″ N, long 122° 07′ 40″ W. The weather was rough and the sighting brief, but the amber flanks and small, curved dorsal fins confirmed the identification. No apparent juveniles were observed; the surface temperature was 13.9°C. This second sighting suggests that this animal may visit these waters more frequently than has been supposed, at a time of year when relatively few vessels are present to observe them.

Fiscus and Niggol (1965) reported sighting "many" *D. delphis* at lat 37° 49′ N, long 123° 26′ W on 22 February 1959, and groups of 4 and 10 in that general vicinity on 4 March of that same year. Brownell (1964) reported 25 on 26 June 1963 at lat 37° 18′ N, 123° 16′ W.

Presence of the common dolphin off central California is possibly a function of anomalous oceanographic conditions. The surface temperatures at the times of the two *D. delphis* sightings reported here were 11.6°C and 13.9°C. The first of these was 2°C below the 20-year mean and the second very nearly at that mean (NMFS 1979). The relatively cool temperature at the first sighting is thought to be due, in part, to vertical mixing resulting from the comparatively rough weather in the winter 1978–79.

Coincidentally, two other typically southern, small Odontoceti species were also sighted within 4 weeks of the first common dolphin sighting. On 4 February 1979, eight or nine *Lagenorynchus obliquidens* (Pacific white-sided dolphin) were sighted at lat 36° 46′ 40″ N, long 122° 04′ 35″ W; on 11 February, five more were sighted at lat 36° 54′ 12″ N, long 122° 01′ 50″ W; and on 22 February, four to six more white-sided dolphins were observed at lat 36° 46′ 42″ N, long 122° 01′ 12″ W. On 22 February, three *Grampus griseus* (Risso's dolphin) were sighted at lat 36° 50′ 30″ N, long 122° 01′ 50″ W, where the surface temperature was 11.4°C. Neither of these species is considered common this far north in California waters, especially *G. griseus.* (See Leatherwood, *et al.,* 1980).

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SPIRONTOCARIS LAMELLICORNIS (*DANA,* 1852), NEW TO THE FAUNA OF SOUTHERN CALIFORNIA (DECAPODA: HIPPOLYTIDAE)

On 27 July 1977, during a series of other trawls conducted by the Southern California Coastal Water Research Project (SCCWRP), a specimen of the shrimp *Spirontocaris lamellicornis* (Dana, 1852) was collected. The specimen was taken in a 10-min. tow off Point Conception at lat 35°22′30″N, long 120°25′54″W, in 183 m of water.

This species occurs sparingly from Unalaska to Point Arena, California at depths of 16–141 m (Rathbun 1904) and has been reported to occur as far south as San Luis Obispo, California in water depths of 150–200 m (Goodwin 1951). The other species captured with this specimen are typical representatives of southern California species found at these depths: *Metacrangon spinosissima, Neocrangon zacae, Pandalus platyceros,* and *P. jordani* (Word and Charwat 1976).

The collection of this specimen extends the known range southwards a distance of only 80 km. The specimen is a healthy appearing adult male with a carapace length of 17 mm. Since this record is an important extension of the species range beyond a well-known faunal barrier (Point Conception, California), it has been deposited in the shellfish museum at the College of Fisheries, University of Washington.

This species is easily distinguished from other members of this genus due to its elevated rostral crest which extends posterior along the carapace and the distinctness of its rostrum (Figure 1). The remaining species of this genus can be distinguished with the following key.

Key to the Northeastern Pacific Species of the Genus *Spirontocaris.*

(This key contains reference to an incompletely known species, *Spirontocaris affinis,* for which epipod and exopod characteristics are unknown. It may therefore be a species of the genus *Lebbeus.*)

1. More than two supraorbital spines 2
— Only two supraorbital spines 3
2. Median spines of carapace are compound, formed of transverse rows of spines joined at the base .... *S. prionota*
— Median spines of carapace are not compound................ *S. affinis*

3. Epipods present on first pereiopods not the second or third ... *S. sica*
— Epipods present on more than first pereiopods 4
4. Epipods present on first and second pereiopods not the third 5
— Epipods present on first, second, and third pereiopods.. 6
5. Rostrum has a thin styliform process and a single ventral tooth at the tip of this process .... *S. holmesi*
— Rostrum with a short tip and lacks ventral tooth .... *S. snyderi*
6. First and second abdominal segments are laterally acute; Rostrum deep with ventral blade drawn forward beyond or meeting the end of the nostral midrib or spine .... *S. lamellicornis*
— First and second abdominal segments are laterally rounded; ventral blade not drawn forward .... *S. dalli*

Comments on the Key

1. Epipods are small, translucent appendages which may function as a gill. They are located on the coxopodite, attached anteriorally and lie appressed to this segment in a posterior direction.
2. Epipods are excellent diagnostic characteristics, as is the appearance of the rostrum, in this genus. The rostrum is however often broken during capture and thus is less useful.
3. Seven other species of *Spirontocaris* are known from regions north of California; therefore, do not use this key for regions where these species may be encountered.

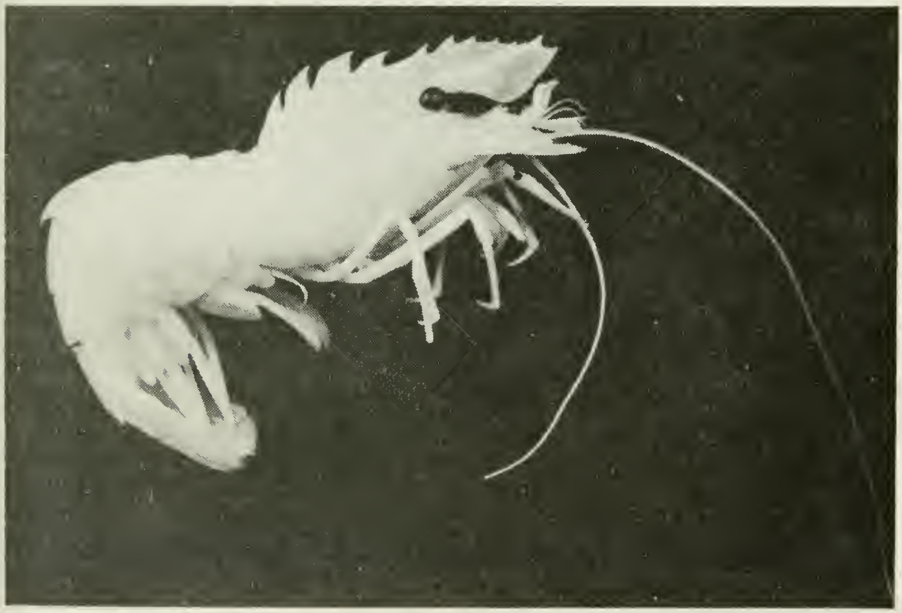

FIGURE 1. *Spirontocaris lamellicornis Photograph by author.*

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BOOK REVIEWS

The Limits and Relationships of the Lutjanidae and Associated Families

By G. David Johnson; Bulletin of the Scripps Institution of Oceanography, Volume 24. University of California Press, Berkeley. 1981. 120 p.

Because of the numerous similar species and the repeated occurrence of the same external characters, the 50 or so families of lower percoid fishes (basses, snappers, grunts, sunfishes, etc.) are inadequately classified. The pioneering electic work of Goslline in the 1960's and several detailed studies of particular families in the 1970's are beginning to provide a sound basis for analysis. Johnson has produced a significant contribution to the definition of three percoid superfamilies: Lutjanoidea, Sparoidea, and Hamuloidea, including their contained families and subfamilies. In addition, several associated problematical genera are reclassified, or at least removed from these superfamilies. North American workers will not find any changes not already included in the 1980 checklist of common and scientific names (Robins *et al.* 1980), and paleontologists will find no reference to fossils. Most of the diversity in these groups is in Indo-Pacific taxa.

After a brief introduction, a materials section and a listing of the proposed classification, the paper goes into a telegraphic characterization of each suprageneric taxon as a "Results" section. Many readers will want to skip this section until after reading the later discussion sections to orient and familiarize themselves with the characters being used and the philosophy of classification of the author.

Several new (or more thoroughly elucidated) character complexes figure prominently in the classification and comprise the strongest part of the paper. These include configurations of adductor mandibulae muscles (including insertions on the jaw bones), relations of the ligaments connecting the head of the maxillary bone to the ethmoid, degree of fusion of the trisegmental dorsal fin pterygiophores, presence of third epibranchial toothplate, number of openings in the pars jugularis of the prootic bone, extent and development of a separate medial lamina of bone of the metapterygoid, presence or absence of a posterior process on the ectopterygoid separating the endopterygoid from the quadrate, patterns of the subpelvic keel and of sub- and post-pelvic processes, arrangement of predorsal bones and presence of the subocular shelf. All of these are discussed well and illustrated and contribute largely to sub- and suprafamilial taxa recognized. The interrelationships of the genera are only lightly touched upon. The Lutjanoidea was examined in greatest detail and an analytical key (to the generic level) and cladogram (to the subfamilial level) are presented only for this group. In contrast to Norman (1966), Johnson recognizes two families Lutjanidae and Caesionidae (rather than just Lutjanidae) and identifies four lutjanid subfamilies (rather than three). Two North American genera, *Verilus* and *Symphysanodon,* are moved to the "oceanic" Percichthyidae and *incertae sedis* status, respectively.

The Sparoidea and Haemuloidea are defined by unique characters that seem derived, but no such character could be found to define the Lutjanoidea. Neither were any unique characters shared among these superfamilies such that they could be cladistically related. This situation exists partly because of the speciose nature of the groups involved, increasing the difficulty of determining the relative primitiveness or advancement of character states. The lack of an adequately defined sister group contributes to the difficulties. Crucial to cladistic analysis is discovery or determination of the closest sister group. However, Johnson based his primitive character states largely on the states in the "primitive" groups, Percichthyidae and Beryciformes, as well as by distribution of character states in immediate (or more distant) sister groups. Indeed, his analysis gives strong support for these superfamilies being closely related. More study of the other closely related families, listed by him as previously associated with the Lutjanidae, may have improved the character analysis, or at least made it more cladistic. This combination of partly cladistic and partly classical evolutionary method of phylogeny construction is the weakest part of the work, and, as the author points out, further knowledge of the numerous other percoid types will clarify many problems. However, the general difficulty of rigorously and unambiguously constructing phylogenies of closely related, speciose groups remains an area of weakness in purely cladistic analysis. A mathematical and cladistic approach to construction of fish phylogenies based on osteological characters by Zehren (1979) demonstrates one possible approach to this problem. Such a study or an exclusively cladistic one (Weitzman, 1974) utilize a large number of characters and stand as rich sources of osteological information to subsequent students of related groups. Johnson's study provides a highly selected suite of characters and descriptive osteology of any lutjanoid is lacking. This limits the interested audience to specialists in these particular groups and leaves the reader unsure about the extent to which other characters were either ignored or were explored and found not useful. Continuing work by Johnson and others will hopefully fill in these gaps.

Few errors were detected in the work, but one surprise was the use of the term opisthotic for the intercalar bone. The latter term is commonly used, particularly since Patterson's (1975; 420–427) convincing argument that the endochondral opisthotic bone of leptolepids and pholidophorids is lost in teleosts (as is the endochondral portion of the intercalar) and the dermal intercalar is all that remains in teleosts. Patterson also recommends (and coins) the term epioccipital for the epiotic bone in teleosts, because primitively this bone had no relation to the otic region. This also avoids confusion with the non-homologus epiotic of *Amia, Lepisosteus,* and a few other actinopterygians. I examined two large dried neurocrania of *Lethrinus nebulosus* to verify Johnson's claim that the lethrinids lack an opisthotic (intercalar). The relations of the bones and sutures in this region are identical of those in *Lutjanus* (Lutjanidae) and *Archosargus* (Sparidae) except that posteriorly a horizontal, transverse suture is lacking between the pterotic above and the intercalar below. This represents a partial fusion of the two bones and not a loss of the intercalar. This positive character state (fusion) can stand as a better character (if consistent) than the more dubious state of reductive loss. In an excellent discussion of the variation and possible significance of the subocular shelf, Johnson notes the lack of the shelf in the scombrids. Conrad (1938) and Starks (1910) noted its presence in *Acanthocybium* and *Scomberomorus* respectively, which I have verified, and it is present also in large dry skeletons of *Thynnus albacares* and *Sarda chiliensis*. It is very thin and delicate in large specimens, and may well be vestigal, ossifying (or calcifying) only at a large size. These discrepancies are only minor oversights in a comprehensive look at several character complexes and do not detract from the significance of the conclusions.

I highly recommend Johnson's paper for a good introduction to percoid systematics and as a source of character states that are useful in these fishes. These characters (and many others) will be needed to adequately classify the remaining percoids and he has put the groups of lutjanid-like fishes on a solid foundation.

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Goose Hunting

By Charles Codieux; Stackpole Books of Harrisburg, PA; illustrated. $15.00 handbook. 197 p.

Codieux covers goose hunting from the first goose (his) to how to cook your goose. In between are nineteen additional chapters in which he discusses the identification of geese, the knowledge needed to successfully shoot a goose, various hunting methods, and the ways of goose hunting from Mexico to Quebec. A philosophical discussion is presented on goose management including the controversial issue of shortstopping or disruption of the goose's instinctive migration path by man's changing of the environment along these paths. The present management of a number of waterfowl refuges holds birds and therefore keeps them from traditional migration patterns. Codieux brings up the question that since shortstopping has resulted in killing more geese but in fewer places, shouldn't the wildlife manager consider his moral or ethical responsibility to distribute goose hunting opportunities?

One short chapter is devoted to the status of geese. Comments from four authorities on waterfowl are given. Nobody really knows what the future will bring. Although it is believed, in general, geese are more abundant in North America today than before, with ever-increasing human population and resulting impacts the future of all wildlife is not optimistic.

Goose hunting would be a valuable reference to waterfowl biologists and managers as well as worthwhile reading to the beginning goose hunter. Oldtimers who believe they are experts at the insane hobby of goose hunting would also benefit.—*James St. Amant*

The Bird Year, a Book for Birders—with Special Reference to the Monterey Bay Area

By John Davis and Alan Baldridge; The Boxwood Press, Pacific Grove, CA; 1980; 222 p.; illustrated; $5.95/softback.

On reading its title, one might expect this little book to be a list of species that a birder could find in a limited geographical area throughout the year. While the book contains that information, it offers much more. The book consists of two parts. The first contains 10 chapters that the authors state: "provide information on what lies behind the seasonal, or cyclic, features of bird biology and indicate why certain activities of birds occur at particular times of the year." Subjects covered include reproduction, breeding behavior, nesting, molts and plumages, and migration. Much of the latest research into these subjects is included and backed up with literature citations.

The second part is a long chapter describing the various habitats of the Monterey area, including species lists, but additionally presenting much information on "habitat related aspects of the biology" of the birds present. Also included in the book are a chapter on the history of ornithology in the Monterey area, an excellent bibliography, appendices of scientific names and bird lists, and an index.

The book has wide application outside the physical area covered. In fact, it would be an excellent text for introductory ornithology courses at the extension or community college level. I found it to be a good refresher course for a field biologist far removed in time from his college ornithology class. I highly recommend it.—*Bruce E. Deuel*

Wildlife Biology

By Raymond F. Dasman, John Wiley & Sons, New York, Second Edition, 1981; 212 p

One of the more pressing limitations on satisfactorily teaching introductory wildlife management at the college level has been the lack of an adequate, up-to-date textbook—a textbook that presents basic wildlife biology principles from a resources management perspective. To complement such a textbook, there are already excellent publications available. These include the smorgasbord of essays edited by James A. Bailey *et al.* (*Readings in Wildlife Conservation,* The Wildlife Society, Washington, D.C., 1974), detailing specific problems in wildlife management and projects designed to resolve them; the equally useful "nuts-and-bolts" technical information in the *Wildlife Management Techniques Manual* (Schemnitz, D., ed., Fourth Edition, Revised, The Wildlife Society, Wash., D.C., 1980); and, of course, the *Journal of Wildlife Management.*

The otherwise obvious choice for the ecology primer would be Dr. Dasmann's 1966 edition of *Wildlife Biology.* Regrettably it is dated, as one would expect and apprehend in a dynamic and rapidly evolving field such as natural resources management.

However, Dasmann, himself, has resolved the dilemma with a new and restructured version of the original publication.

Although basically identical in topic outline to the first edition, the 1981 edition is very much a new book. Only the prose of the chapters discussing population dynamics and the regulation of animal numbers would be relatively familiar to readers of the 1966 edition. However, these chapters, too, are revised to update obsolete information and data interpretation. The balance of the text and most of the reference material are new. Concepts and wildlife management principles are presented cogently and succinctly and in a style that would appeal to the interested beginning student. The frequent recourse to wit and wry comment is not distracting, but rather serves to emphasize some of the frustrating gaps in present knowledge or contradictions in the results of recent attempts to resolve certain problems. Technical terms are kept to a minimum and appropriately defined where they are utilized. Regrettably, the same can not be said for many recent publications in ecology intended for the general reader and the beginning student.

The final portion of the text is a comprehensive review of the perilous status of much of the world's wildlife resources. This situation has occurred in spite of the many sincere efforts—and even greater number of avowed intentions—by governments and organizations to reverse the unfortunate, exponentially accelerated trend in habitat loss and quality deterioration. Efforts at international assistance to underdeveloped nations to manage their natural resources and to establish natural reserves are discussed. These are compared to the inadequacy of protection and resources management in many such protected areas and to the insidious inroads of commercial trade in animal products. Dasmann emphasizes the need for those who control the appropriate technical and political instruments to work diligently and promptly to manage and protect wildlife resources. Dasmann also challenges the readers themselves to participate in the effort. All of this serves to emphasize the pressing need for more and better trained wildlife resource protection managers and a more informed and understanding public to assist in inhibiting the decline of wildlife resources. This information and understanding are superlatively well presented in Dasmann's timely and extremely useful revision. I recommend it highly.—*Bruce G. Elliott*

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