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ICHTHYOPLANKTON OF LAKE HAVASU, A COLORADO RIVER IMPOUNDMENT, ARIZONA-CALIFORNIA [1]

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Eight fish species representing six families were identified among ichthyoplankton samples taken from Lake Havasu, Arizona-California, during springs of 1985 and 1986. Threadfin shad, *Dorosoma petenense;* common carp, *Cyprinus carpio;* and sunfishes, *Lepomis* spp., were predominant, with fewer numbers of razorback sucker, *Xyrauchen texanus;* black crapple, *Pomoxis nigromaculatus;* largemouth bass, *Micropterus salmoldes;* channel catfish, *Ictalurus punctatus;* and striped bass, *Morone saxatilis.* Although the razorback sucker reproduces upstream in Lake Mohave, larvae captured during this study constitutes the first evidence of spawning by this species in Lake Havasu since the 1950s.

INTRODUCTION

Mainstream impoundments on the lower Colorado River support important recreational fisheries for non-native fish species. Some, like rainbow trout, *Salmo gairdneri,* are maintained by hatchery plants while other species, such as largemouth bass, *Micropterus salmoides,* and channel catfish, *Ictalurus punctatus,* rely largely on natural reproduction. Although knowledge of larval distribution, abundance, and ecology is important for assessing fish populations (e.g., Lagler 1956, Nikolsky 1963, Braum 1978), no larval fish reports have been published for the lower Colorado River since 1954 (Winn and Miller 1954). California Department of Fish and Game (CDFG) netting for larval striped bass, *Morone saxatilis,* in Lake Havasu, Arizona-California (Giusti and Milliron 1988), provided an opportunity to determine the occurrence of other fish species.

STUDY AREA

The study area (Figure 1) comprised two distinct sections: 1) a relatively cold (<20°C), upstream river reach beginning 67 km downstream from Davis Dam and flowing 27 km through Topock Gorge; into 2) a warmer (to 24°C), downstream lentic portion (Lake Havasu). The river reach has current velocities exceeding 30 cm/s and averages less than 0.15 km wide and 5 m in depth. Lake Havasu is a storage and diversion reservoir impounded when Parker Dam was completed in 1938. It is 42 km long, 0.4 to 4.4 km wide and averages 9–10 m in depth; maximum depth rarely exceeds 18 m.

MATERIALS AND METHODS

Four and 16 sampling stations were established in the river and reservoir reaches, respectively (Figure 1) (Giusti and Milliron 1988). Larval fishes were collected with a 1.0-m^2, conical plankton net (1.13 m mouth diameter, 3.0 m long and 505 μm mesh) towed diagonally at 0.76 m/s from bottom to surface

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for 5 min at river stations and 10 min at reservoir stations from 5 March to 27 June 1985. Sampling was concentrated at six of the reservoir stations from 28 February to 12 June 1986; sampling at the four river stations was suspended in 1986 due to high flows. Samples were collected twice weekly at river and thrice weekly at reservoir stations, respectively; inclement weather or equipment malfunctions sometimes precluded sampling. Surface water temperature was measured at each station with a multiparameter probe.

Specimens were fixed in 10% formalin and later stained with Rose Bengal, sorted and identified, and developmental stage of individual larva was determined (Snyder 1981). Identifications were made by use of keys, descriptions, and illustrations in Winn and Miller (1954), Mansueti and Hardy (1967), May and Gasaway (1967), Lippson and Moran (1974), Conner (1979), Snyder (1979, 1981), and Wang (1981). Mean monthly catch per unit effort (CPE) was calculated by dividing the number of larvae collected by the total number of tows for each month, and is expressed as the average number of larvae per tow.

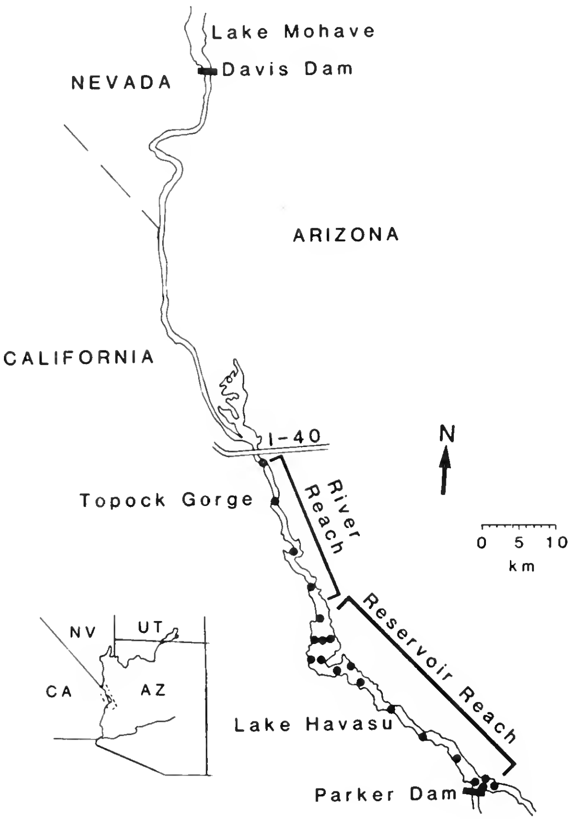

FIGURE 1. Lower Colorado River and Lake Havasu study area, Arizona-California, and vicinity map (inset). Solid circles denote approximate locations of larval sampling stations.

RESULTS AND DISCUSSION

Eight species representing six families were among the 6,617 larvae collected (Table 1); all *Lepomis* that could be positively identified were bluegill, *L. macrochirus;* however, other *Lepomis* were also present. Common carp, *Cyprinus carpio,* was the most abundant taxon in both years, 49% and 56% of total larvae, followed in 1985 by *Lepomis* spp. (29%, mostly bluegill, but also including other, undetermined species of *Lepomis*), threadfin shad, *Dorosoma petenense,* largemouth bass and black crappie, *Pomoxis nigromaculatus.* In 1986, the second most numerous fish was threadfin shad (37%). Relative abundance of centrarchids was much lower in 1986 when they comprised only 3% of the total. Channel catfish, striped bass, and razorback sucker, *Xyrauchen texanus,* composed the remainder, with each accounting for ≤ 2% of the total each year (Table 1). All species were found in both river and reservoir samples; however, all were notably more abundant in the latter. The strongly flowing, relatively cold, river reach was apparently not favored for spawning by many of these predominantly warm-water fishes.

TABLE 1. Larval Fishes Sampled from the Colorado River at Lake Havasu, Arizona-California, March through June, 1985 and 1986.

		1985		*1986*	
Family	*Species*	*No.*	*(%)*	*No.*	*(%)*
Clupeidae	*Dorosoma petenense*	964	(19)	553	(37)
Cyprinidae	*Cyprinus carpio*	2,524	(49)	831	(56)
Catostomidae	*Xyrauchen texanus*	8	(<1)	29	(2)
Ictaluridae	*Ictalurus punctatus*	13	(<1)	0	(0)
Percichthyidae	*Morone saxatilis*	5	(<1)	37	(2)
Centrarchidae	*Lepomis* spp.	1,475	(29)	33	(2)
	Micropterus salmoides	4	(<1)	4	(<1)
	Pomoxis nigromaculatus	121	(2)	4	(<1)
	undetermined	12	(<1)	0	(0)
Totals		5,126		1,491	

Total CPE was lower by a factor of about three in 1986 than 1985 (Table 2). Threadfin shad CPE in 1986 was about 80%, carp CPE about 34%, and centrarchid CPE about 3% that of 1985. These differences may reflect changes in reproductive success or in spatial distribution of spawning activity and/or larvae.

Because timing of spawning, incubation, and hatching varies among species and with environmental conditions, taxonomic composition of larval collections changed over the course of sampling (Table 2). Razorback sucker appeared earliest, at the beginning of March, and was first to disappear; few individuals were collected after April. A similar pattern and timing have been observed in Lake Mohave (Marsh and Langhorst 1988). Other taxa began to appear in mid-March, and persisted into June. In both years, carp abundance was greatest in May, while threadfin shad and centrarchid larvae were most abundant in June (Table 2).

TABLE 2. Mean Monthly Catch Per Unit Effort of Larval Fishes (Number per Tow) from the Colorado River at Lake Havasu, Arizona-California, March through June, 1985 and 1986.

	1985				
	MAR	*APR*	*MAY*	*JUN*	*MAR-JUN*
Clupeidae	0	1.6	2.5	19.2	5.8
Cyprinidae	0.1	1.9	28.6	23.3	13.5
Catostomidae	0.2	0.1	<0.1	0	0.1
Ictaluridae	0	0	<0.1	0.3	0.1
Percichthyidae	0	0	<0.1	0.1	<0.1
Centrarchidae	0.2	1.7	3.4	34.3	9.9
Totals	0.5	5.3	34.6	77.2	29.4[1]
Number of tows	18	54	53	39	164

	1986				
	MAR	*APR*	*MAY*	*JUN*	*MAR-JUN*
Clupeidae	0	1.8	2.2	14.8	4.7
Cyprinidae	0	6.2	7.3	4.8	4.6
Catostomidae	0.4	<0.1	<0.1	0	0.1
Percichthyidae	0	0.2	0.3	0.3	0.2
Centrarchidae	<0.1	0.3	0.2	0.8	0.3
Totals	0.4	8.5	10.0	20.7	9.9[1]
Number of tows	66	42	63	23	194

[1] unweighted means

Threadfin shad spawning usually occurs in spring when water temperatures reach 21°C (Kimsey 1958, Gerdes and McConnell 1963, Lambou 1965). Carp move into shallows and spawn initially at about 16°C, and attain peak activity at 18 to 20°C (Greely 1927, Sigler 1958). Bluegill, the most abundant centrarchid in our samples, has a protracted spawning season that may extend from spring through autumn at water temperatures of 19 to 27°C (reviewed by Emig 1966a). Largemouth bass spawning occurs at 16 to 24°C (Emig 1966b), while black crappie reproduces at 14 to 18°C (Goodson 1966). Midwater temperature in Lake Havasu was less then 13°C at initiation of study in 1985, attained 18°C by mid-April, and remained above 21°C after the first week of May (Giusti and Milliron 1988). Temperature in 1986 was nearly 16°C when sampling began, reached 18°C by 1 April, 20°C by 1 May, and remained above 21°C after mid-May. Thus, timing of species reproduction, as evidenced by occurrence of larvae, followed predictable patterns based upon water temperatures.

Twenty-seven fish species have been recorded from the study area (Minckley 1979, Marsh et al. 1988). We identified larvae of only eight forms. Among native kinds, Colorado squawfish, *Ptychocheilus lucius,* is extirpated, and bonytail, *Gila elegans,* is extremely rare. Four non-native species, white sturgeon, *Acipenser transmontanus;* brown bullhead, *Ameiurus nebulosus;* white crappie, *P. annularis;* and mottled sculpin, *Cottus bairdi,* were relegated to hypothetical status by Minckley (1979), because reproducing populations have not been established; larvae were thus not expected. Rainbow trout below Davis Dam are maintained by stocking, and natural reproduction is limited in the area. Among non-native cyprinids, goldfish, *Carassius auratus;* golden shiner, *Notemigonus crysoleucas;* red shiner, *Notropis lutrensis;* and fathead minnow, *Pimephales promelas,* have been widely used for bait along the lower Colorado River (Miller 1952), although only red shiner appears to reproduce in significant numbers. Other species present but not encountered were flathead catfish, *Pylodictis olivaris;* black bullhead, *A. melas;* yellow bullhead, *A. natalis;* mosquitofish, *Gambusia affinis;* smallmouth bass, *M. dolomieui;* green sunfish, *L. cyanellus;* and redear sunfish, *L. microlophus.* These seven species occupy benthic regions or marginal habitats such as backwaters, or are rare-to-uncommon in the area; we are not surprised they were absent from collections. Larvae of the several *Lepomis* species are notoriously difficult to identify, and may have gone undetected among samples.

Larval razorback suckers obtained during this survey must represent natural reproduction in the study area. Langhorst and Marsh (1986) suggested that larvae hatched in Lake Mohave (Figure 1), immediately upstream from the study area, might be transported out of that reservoir, entrained with hypolimnetic water released through Davis Dam. Passive travel time downstream for 136 km to Parker Dam is at least 13.2 days, assuming discharge and velocity recorded in April 1986. Larval razorback suckers, hatched and developed to late protolarval (swim-up) stage above Davis Dam, should be approximately 23 days old, 12 to 15 mm long, and approaching or in the metalarval stage (Minckley and Gustafson 1982) upon arrival in lower Lake Havasu. However, all collected specimens were proto- or mesolarvae and averaged only 9.5 ± 0.7 mm long ($n = 23$); the largest was 10.8 mm. It is thus improbable that they were produced upstream in Lake Mohave. Although razorback suckers spawned below Davis Dam and in Lake Havasu in the 1940s and 1950s (Douglas 1952, Jonez and Sumner 1954), we are unaware of any documented reproduction by the species since then.

ACKNOWLEDGMENTS

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SEASONAL ABUNDANCE AND FEEDING HABITS OF SHARKS OF THE LOWER GULF OF CALIFORNIA, MEXICO [1]

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Eleven species of sharks are commonly caught commercially off Isla Cerralvo, Mexico. The scalloped hammerhead, *Sphyrna lewini,* smooth hammerhead, *Sphyrna zygaena,* and silky shark, *Carcharhinus falciformis,* are most frequently captured from March through December. The sicklefin smooth-hound, *Mustelus lunulatus,* is captured during all seasons except from June to August. Mostly adult mexican hornsharks, *Heterodontus mexicanus,* are caught from December through May. Sex ratios of the sicklefin smooth-hound, scalloped hammerhead, and Pacific angel shark, *Squatina californica,* deviated from a 1:1 ratio; whereas, those for the other species did not. Gut contents of three species were analyzed. The sicklefin smooth-hound feeds primarily on benthic crustaceans and fishes; the scalloped and smooth hammerheads prey mainly on neritic fishes and mesopelagic cephalopods.

INTRODUCTION

Although the species composition of sharks in the Gulf of California has been described (see Beebe and Tee-Van 1941, Berdegue 1956, Rosenblatt and Baldwin 1958, Castro-Aguirre 1967, 1978, and Applegate *et al.* 1979), their seasonable abundance and feeding habits are not well known. Hernandez-Carvallo (1967) found the scalloped hammerhead, *Sphyrna lewini,* bonnethead, *Sphyrna tiburo,* and scoophead, *Sphyrna media,* throughout the year, the smooth hammerhead, *Sphyrna zygaena,* from October through April, and the great hammerhead, *Sphyrna mokarran,* throughout late spring and summer. Based on examinations over a year of commercial shark landings south of Mazatlan, Diaz *et al.* (1982) noted that eight species were of commercial importance. The scalloped hammerhead, in 35% of the total catches, was the most common species. The blacktip, *Carcharinus limbatus,* and Pacific sharpnose shark, *Rhizoprionodon longurio,* were also frequently caught. The scalloped hammerhead, although present throughout the year, was most common during May. The blacktip was only caught from March until June. In a survey of the demersal fisheries on the eastern side of the Gulf of California, Ehrhardt (pers. comm.) noted that many gray smooth-hound, *Mustelus californicus,* were caught during the winter but few during the summer. Klimley (1982) observed scalloped hammerheads from late spring until late fall at offshore seamounts in the Lower Gulf of California.

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For shark populations in the Gulf of California, sizes, sex ratios, and feeding habits have been determined only for the scalloped hammerhead. Offshore schools of this species were shown from direct observation (Klimley and Nelson 1981, Klimley 1985) and underwater stereophotographs (Klimley 1982, 1987, Klimley and Brown 1983) to be composed primarily of females. This species was found to feed on crustaceans, fishes, and cephalopods from both the neritic (over depths less than 200 m) and pelagic habitats (over depths greater than 200 m) [Klimley 1982, 1987].

In our study we describe the seasonal abundance, size distribution, sex ratios, and stomach contents of the most frequently captured species of sharks as well as a list of all species caught in the Lower Gulf of California.

MATERIALS AND METHODS

Sharks were caught by fisherman from four fishing camps, Sargento, Ventana, Las Salinas, and Cueva de Leon, off the southern tip of Isla Cerralvo (lat 24° 12'N, long 109° 48'W) (Figure 1). Isla Cerralvo is separated from the eastern side of the Baja California peninsula by a channel 13 km wide with depths to 500 m. Due to its position at the entrance to the Gulf, the area is considered to be a transitional zone with a very complicated and dynamic oceanographic structure. At the surface three water masses can be detected: 1) cold California Current water with a low salinity, 2) warm eastern tropical Pacific water with an intermediate salinity and 3) warm, highly saline Gulf of California water. Detailed information on the oceanographic properties of water masses in this area is given by Alvarez-Borrego (1983), Roden (1958), and Roden and Groves (1959). Three capture methods were used: 1) set lines, 2) gillnets, and rarely 3) harpoons. The lines and gillnets were deployed at depths ranging from 50 to 200 m. These methods are described in Applegate et al. (1979).

Sampling was carried out once or twice weekly from June 1981 to Aug. 1982 and from Oct. to Nov. 1984. The sharks were identified, measured, and sexed, and stomach contents were removed and preserved in formalin.

The Index of Relative Importance (IRI), introduced by Pinkas (1971), was used to express the signifiance of different prey items:

$$IRI = (N+V)\,F \quad \text{where}$$

N is the numerical percentage of the prey item,

V is the volumetric percentage of the prey item, and

F is the percentage of stomachs containing the item.

The IRI percentages were plotted in circular diagrams. The habitat of the prey was added, using Miller and Lea (1972), Roper and Young (1975), and Brusca (1980) for the fishes, cephalopods, and crustaceans, respectively.

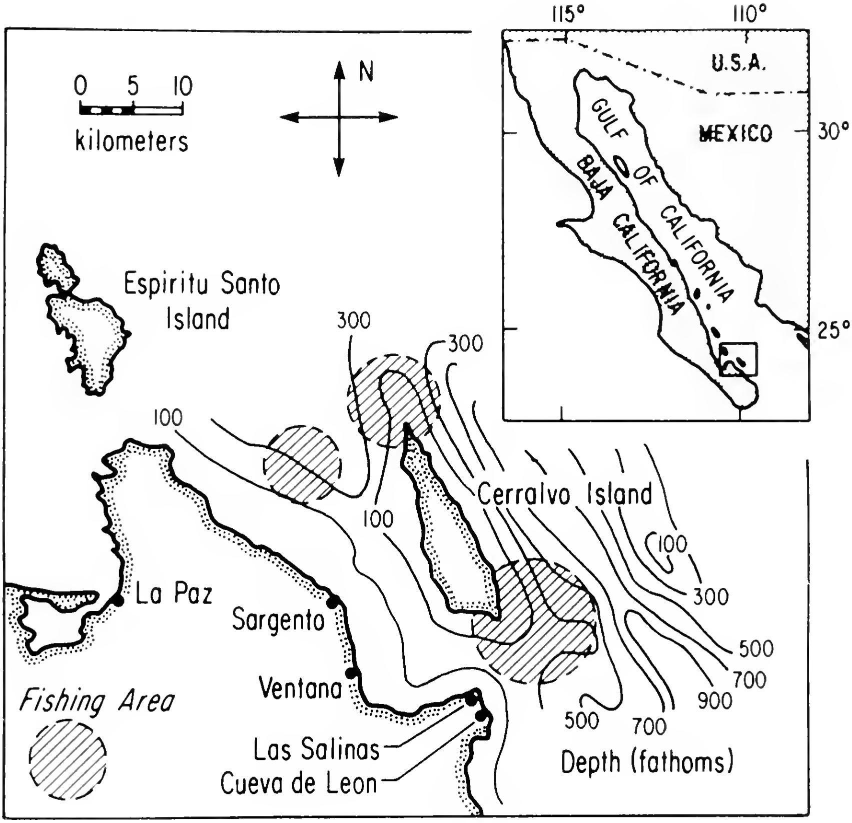

FIGURE 1. Bottom topography surrounding Isla Cerralvo with locations of fishing camps and fishing grounds indicated.

RESULTS

Nineteen species were recorded from the waters surrounding Isla Cerralvo during our year long study (Table 1). Most frequently caught were the sicklefin smooth-hound, *Mustelus lunulatus,* and the mexican hornshark, *Heterodontus mexicanus,* each composed 31% of the total catch. Also, *S. lewini* (20%) was often caught. Considerably less commonly captured were Pacific angel sharks, *Squatina californica,* (8%), silky sharks, *C. falciformis* (4%), *S. zygaena* (4%), and *R. longurio* (2%).

During the spring *H. mexicanus, M. lunulatus,* and *S. lewini* were most frequently caught (Figure 2). In the summer months *S. lewini* was the most commonly captured species, but two other species, *C. falciformis* and *S. zygaena,* were also frequently caught. In the autumn only one species, *H. mexicanus* was often captured. During winter the temperate species, *H.mexicanus, M. lunulatus,* and *S. californica,* were commonly caught.

TABLE 1. Species Recorded in the Gulf of California by Seven Authors: 1) Beebe and Tee-Van 1941, 2) Rosenblatt and Baldwin 1958, 3) Kato 1965, 4) Castro-Aguirre 1967, 5) Kato et al. 1967, 6) Hernandez-Carvallo (pers. comm.), 7) Applegate et al. 1979, and 8) This Paper. X = Present, R = Rare, O = Occasional, and A = Abundant. The Taxonomic Divisions are Based on Compagno (1984 a, b).

Order-Common Name *Family* Species	1	2	3	4	5	6	7	8
Hexanchiformes-Frilled and Cow Sharks								
Hexanchidae								
Notorynchus cepedianus						X		
Squaliformes-Dogfish Sharks								
Echinorhinidae								
Echinorhinus cookei								R
Squatiniformes-Angel Sharks								
Squatinidae								
Squatina californica					X		X	A
Heterodontiformes-Bullhead Sharks								
Heterodontidae								
Heterodontus francisci	X			X	X			
mexicanus				X			X	A
Orectolobiformes-Carpet Sharks								
Ginglymostomatidae								
Ginglymostoma cirratum	X		X	X	X	X	X	R
Rhiniodontidae								
Rhiniodontus typus	X						X	R
Lamiformes-Mackerel Sharks								
Odontaspididae								
Odontaspis ferox								R
Alopiidae								
Alopias superciliosus							X	
vulpinus						X		
Cetorhinidae								
Cetorhinus maximus				X	X			
Lamnidae								
Carcharodon carcharias				X	X		X	R
Isurus oxyrinchus					X	X		R
Lamna ditropis				X				
Carcharhiniformes—Ground Sharks								
Scyliorhinidae								
Cephaloscyllium ventriosum				X			X	
Cephalurus cephalus	X			X	X			
Galeus piperatus				X	X			
Parmaturus xaniurus				X	X			
Triakidae								
Galeorhinus galeus							X	
Mustelus californicus	X		X	X	X	O		
dorsalis	X				X			
henlei				X	X			
lunulatus	X		X	X	X	A		A
Triakis semifasciata			X	X	X		X	
Carcharhinidae								
Carcharhinus albimarginatus	X						X	
altimus			X			O	X	
falciformis				X	X			A
galapagensis			X					
leucas	X		X		X	O	X	O
limbatus	X	X	X	X	X	X	X	R
longimanus							X	
obscurus					X		X	R
porosus		X	X	X	X	O	X	
Galeocerdo cuvier	X	X					X	R
Nasolamia velox	X	X	X	X	X	O	X	R
Negaprion brevirostris	X		X	X	X		X	R
Prionace glauca	X			X			X	
Rhizoprionodon longurio	X		X	X		A		R
Sphyrnidae								
Sphyrna corona					X		X	
lewini			X	X		A	X	A
media	X		X	X	X	A	X	
mokarran			X	X	X	O	X	
tiburo			X	X	X	A	X	
tudes	X							
zygaena	X		X	X	X	R		A

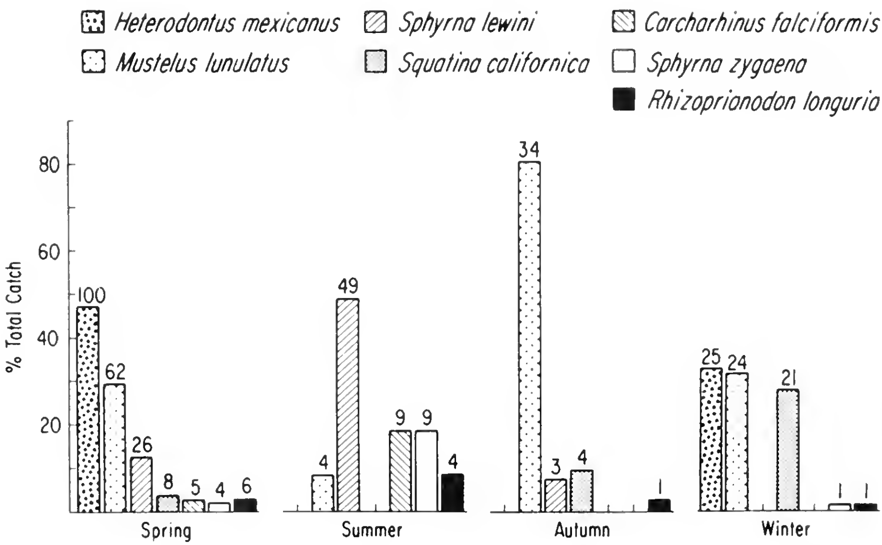

FIGURE 2. Relative abundance (% total catch) of seven most frequently captured shark species for each season. The numbers above the bars refer to the number of sharks of that species caught during that season. The seasons were defined as follows: June to Aug. (summer), Sept. to Nov. (autumn), Dec. to Feb. (winter), and March to May (spring).

Sex ratios for some species varied between seasons. Male *H. mexicanus* were caught more frequently than females during spring (Figure 3) (Chi-square Test [equal frequencies], $p=0.01$) yet similar frequencies of each sex were captured during winter. For *M. lunulatus,* males were less frequently caught than females in the spring (Chi-square Test, $p=0.02$), yet during the fall males were caught more often than females ($p=0.01$). Males of *S. lewini* were caught more often than females in the spring (Chi-square Test, $p=0.02$) whereas the frequencies of individuals of both sexes caught during the summer were similar. Males of *S. californica* were caught more commonly than females during the winter (Fisher's Exact Probability Test, $p=0.04$), however, the smallness of the sample sizes during spring and fall precluded statistical testing of skewed sex ratios at these times.

Sphyrna zygaena was the largest of the most commonly captured species with a mean length of 2172 mm. *Sphyrna lewini* was slightly smaller with a mean of 1896 mm. The mean sizes of *C. falciformis* and *M. lunulatus* were 1883 and 1021 mm, respectively. There were seasonal differences in lengths in four species, *S. lewini., S. californica, S. zygaena, C. falciformia* (Figure 4). For *S. lewini,* the mean length increased from 1521 mm in spring to 2415 mm during summer. For *S. californica,* smaller females were captured in spring and larger females in summer. Males, which were intermediate in size, were caught only during the winter. For *S. zygaena,* smaller individuals were caught during summer months. Similarly, *C. falciformis* captured in the summer were smaller than those caught in the spring. *C. falciformis* females were larger than males during the summer.

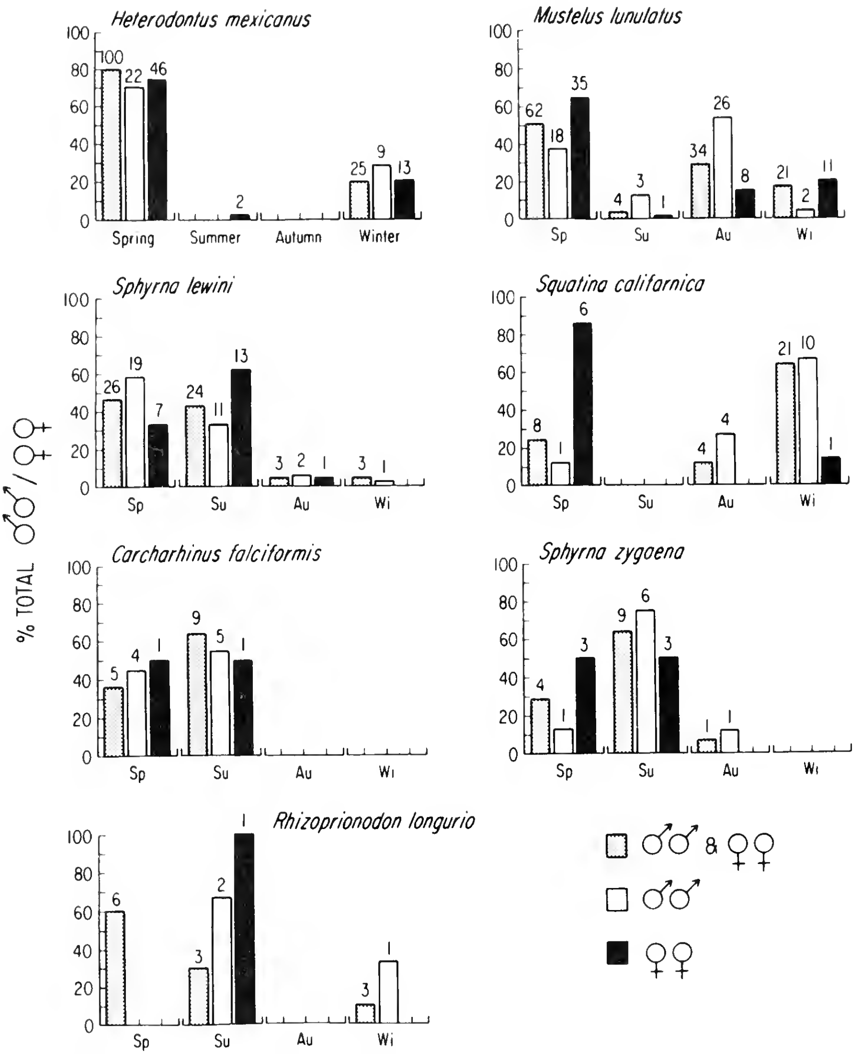

FIGURE 3. Histograms for the seven most common shark species of the percentages of males, females, and individuals of both sexes caught each season relative to their yearly totals. The number of captures in each group indicated above histogram bar.

All stomachs of captured *S. lewini* and *S. zygaena* contained prey. *Carcharhinus falciformis* and *M. lunulatus* had prey in 87.8 and 73.3% of their stomachs, respectively. *Heterodontus mexicanus* had prey in 66.6% of their stomachs. *Squatina californica* had prey in only 4.5% of their stomachs.

The stomach contents of *M. lunulatus, S. zygaena,* and *S. lewini* are shown in Figure 5. *Mustelus lunulatus* fed almost exclusively on fishes (53.3% of total IRI) and crustaceans (46.7%). The decapod crab, *Mursia gaudichaudii,* was the most important species in the shark's diet, while a scorpionfish, *Scorpaena* sp., was also of moderate importance. Two fishes, the garden eel, *Taeniconger*

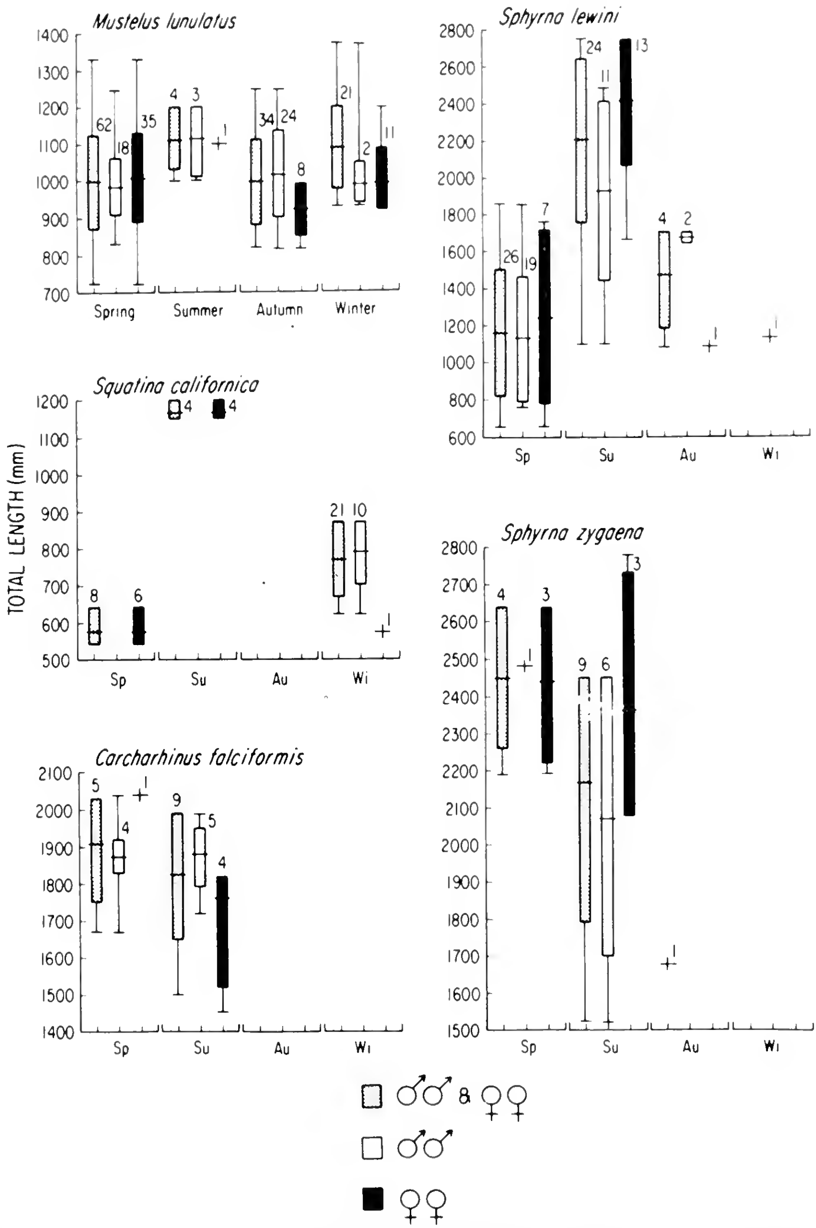

FIGURE 4. The mean, ±1 SD, and ranges of the total lengths of males, females, and individuals of both sexes for the different seasons given for five most commonly captured species of sharks.

canabus, and the midshipman, *Porichthys notatus,* and one crustacean, the spiny mole crab, *Blepharipoda occidentalis,* were less important. The hammerhead species fed primarily on neritic fishes and mesolpelagic cephalopods.

Although the stomachs of *S. zygaena* often contained fishes (57.8%), the only species that could be identified were the cownose ray, *Aetobatus narinari,* and the California needlefish, *Strongylura exilis.* Stomachs also contained the cephalopods, *Histioteuthis heteropsis, Onychoteuthis banksi,* and *Cranchiidae* sp. For *S. lewini,* fish species composed 64.8% of the IRI with prey such as the chub mackerel, *Scomber japonicus,* black skipjack, *Euthynnus lineatus,* and a goatfish (Mullidae). Cephalopods were also common (30.1%) in the stomachs of the scalloped hammerhead with the *Octopus* sp., *Vampyroteuthis infernalis,* and *Histioteuthis heteropsis* most important. A mantis shrimp, *Squilla biformis,* was also present in the diet of this species. The pelagic red crab, *Pleuroncodes planipes,* was found in large numbers in the stomachs of *C. falciformis. Heterodontus mexicanus* fed exclusively on benthic crustaceans and fishes.

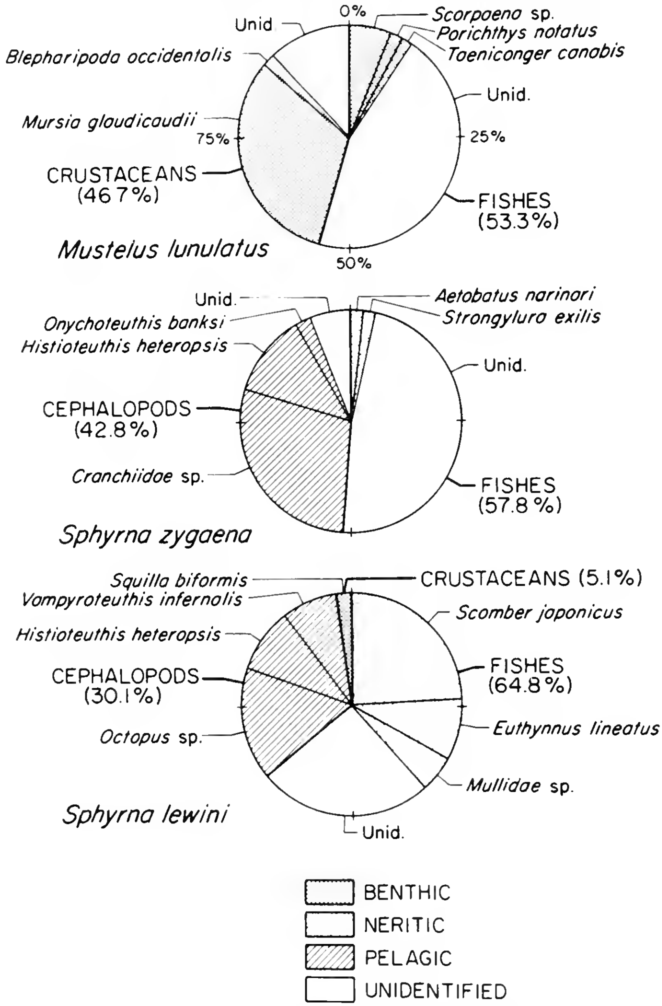

FIGURE 5. Stomach contents of the sicklefin smooth-hound, *M. lunulatus,* scalloped hammerhead, *S. lewini,* and smooth hammerhead, *S. zygaena.* The prey are ordered firstly by habitat and secondly by Index of Relative Importance.

DISCUSSION

Of the 47 species of sharks recorded for the Gulf of California, 19 were caught during our study (Table 1). The low species diversity in our study is probably partly due to our sampling catches along a relatively short section of coastline between Loreto and Cabo San Lucas. Most of this area lies within the lower Gulf of California zoogeographic zone, described by Walker (1960) and Thompson *et al.* (1979) from the characteristic fish fauna. The northern boundary of this zone lies along an imaginary line drawn between La Paz and Guaymas. A line from Cabo San Lucas to Mazatlan delimits the southern boundary. Furthermore, many species reported by other authors were caught infrequently near Mazatlan where water temperatures are usually higher than within the Gulf of California. These tropical species may be at the edge of their range, not moving any farther northward into the Gulf. Finally, data for this fishery was compiled over 40 years, while that for ours over only a year.

Comparison of our species list with that of Hernandez-Carvallo (pers. comm.) and Diaz *et al.* (1982), both based on records from the Mazatlan area, indicates that three species are commonly caught on both sides of the Gulf of California: *M. lunulatus, S. lewini,* and *S. zygaena. Heterodontus mexicanus, C. falciformis,* and *S. californica,* often captured near Isla Cerralvo, were less commonly captured on the eastern side of the Gulf. On the other hand, *M. californicus, R. longurio, C. porosus,* the bignose shark, *Carcharhinus altimus,* the whitenose shark, *Carcharhinus velox,* the bull shark, *Carcharhinus leucas,* the bonnethead, *Sphyrna tiburo, S. media,* and *S. mokarran,* reported to be abundant along the west coast of Mexico within the Gulf by Hernandez-Carvallo (pers. comm.), were either not caught or seldom captured at Isla Cerralvo. This observation illustrates the variability in species composition and abundances in the lower Gulf of California, probably caused by the complex hydrography of this zone. However, regional differences in public preferences for particular sharks and variability in local fishing techniques may confound these comparisons.

Only adults of most species were caught. The mean sizes of *S. lewini* caught during two consecutive summers (2415 and 2464 mm) were considerably larger thanthose measured by underwater stereophotography by Klimley (1982) during the summer of 1980 and 1981, ranging from 1525 mm at Las Arenitas to 2110 mm at El Bajo Gorda. This may be due to segregation by size at different locations (Klimley 1987) and/or by the different sampling techniques. The striking interannual similarity of the average lengths during the summers observed by Klimley (1982) at one seamount, and the difference between mean population size between spring and summer at another seamount indicates the tendancy for this species to segregate by sex. On the other hand, the mean size of 1908 mm for *C. falciformis* is similar to the 1927 mm average length for 12 shark caught by longline in the open Pacific, reported by Strasburg (1958).

The seasonal presence of the scalloped hammerhead within the Gulf of California, based on direct observations by Klimley (1982), coincides with our results. The year round presence of this species and *S. zygaena* in waters close to Mazatlan, according to Hernandez-Carvallo (pers. comm.) and Diaz *et al.* (1982), indicates that both species probably migrate northward into the lower

Gulf during late spring and early summer. Other species such as *C. falciformis* also may be seasonal, migrating into the Gulf during the summer. *Heterodontus mexicanus* and *S. californica*, most common during winter, probably move southward into the upper Gulf during summer.

The length differences between males and females *S. lewini* in our study coincide with those of Klimley (1982, 1985, 1987). He found that large males were not common within schools of this species. We also observed a similar difference between male and female *S. zygaena.* The percentages of stomachs with prey varied among species. Strasburg (1958) found that 25% of the stomachs of *C. falciformis* contained prey, while we found 87.8% had food items. Klimley (1982) found that 67% of the scalloped hammerhead sharks had prey in their stomachs, while we found full stomachs in 100% of *S. lewini* in this study. The prey composition of the diet of *S. lewini* in this study corresponds well with those findings of Bass et al. (1973), Clark (1971) and Klimley (1982) in South African, Hawaiian, and Gulf of California waters, respectively. The feeding habits of *M. lunulatus* were similar to those of other members of the same genus such as narrowfin smooth-hound, *Mustelus norrisi*, and brown smooth-hound, *Mustelus henlei*, studied by Clark and von Schmidt (1965) and Russo (1975) in Florida and California, respectively.

ACKNOWLEDGMENTS

We are very grateful to those fishermen who allowed us to make measurements on the sharks they captured and to preserve the stomach contents from these sharks. Richard R. Rosenblatt offered useful editorial advice. This report is based on the undergraduate study of the first author at Centro Interdisciplinario de Ciencias Marinas, Instituto Politecnico Nacional in La Paz.

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Calif. Fish and Game 75(2): 85–101 1989

WETLAND BIRD SEASONAL ABUNDANCE AND HABITAT USE AT LAKE EARL AND LAKE TALAWA, CALIFORNIA[1]

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A study of wetland bird composition, seasonal abundance, and habitat use was conducted on Lake Earl and Lake Talawa in Del Norte County, California from July 1974 through February 1976. Ninety-five species were recorded. Most birds occurred from October to December and during March and April. Diving ducks occurred primarily during fall and winter and were more abundant than surface-feeding waterfowl. Surface-feeding ducks occurred mostly during early and mid fall. Shorebird numbers were highest during spring and fall. The American Coot was the most abundant species recorded. Of all birds recorded, 69% used open water and 11% used flooded or bare mud and sand flats. Sand shores supported the highest densities of birds. Eleven species used six of the seven available habitat types. Freshwater marsh, mud/sandflat, and sand shore habitat types were preferred over other available habitat types. The lakes are an important wetland to migrating birds.

INTRODUCTION

California originally had 20,200 km^2 of wetlands, including about 1,540 km^2 along the coast. To date, almost 91% of the State total and 70% of the coastal wetlands have been destroyed. Most of the latter loss has resulted from agricultural, urban-industrial, and harbor development (U.S. Fish and Wildlife Service, 1979. Concept plan for waterfowl wintering habitat preservation, California coast. Unpbl. rep., Region 1, Portland, OR. 122 p. plus appendices.). The importance of wetlands is well known (Greeson, Clark and Clark 1979, and Tiner 1984). Baseline information is needed on wetlands to determine management plans and in measuring the effects of future natural or man-made changes on bird use and habitat quality.

The importance of Lake Earl and Lake Talawa in northern coastal California to migratory birds is not well known, Studies by Hehnke (Hehnke, M. 1969. Bay and estuary report, Big Lagoon, Stone Lagoon, Freshwater Lagoon, Lake Earl, Lake Talawa, July 1969 to October 1969. Unpubl. rep. Calif. Dept. Fish Game, Eureka. 37 p.), Stoudt (Stoudt, J. H. 1970. Delineation of primary canvasback migration and wintering habitat, 1968-69. U. S. Fish and Wildl. Serv., Northern Prairie Wildl. Res. Ctr., Jamestown, ND. Work Unit NA-404.2. Completion rep. 29 p. plus fig.), Peters (Peters, W. 1971. Lake Earl waterbird census study, 1970-71. Calif. Dept. Fish Game., Fed. Aid Wildl. Rest. Proj. W-54-R-3. 9p.), Monroe et al. (1975) and Widrig (Widrig, R. S. 1977. Spring nesting and fall migration observations of shorebirds at Lake Talawa, Del Norte County,

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California. Unpubl. rep. on file Humboldt State Univ. Library, Arcata, CA. 6 p. plus appendices) have provided some information on the seasonal use of the lakes by wetland birds, whereas other aspects of use have been reported by Yocom and Wooten (1956), the U.S. Fish and Wildlife Service (U. S. Fish and Wildlife Service, 1961. Biological reconnaissance of the Lake Earl area, Del Norte County, California. Unpubl. rep., Region 1, Portland, OR. 18 p.). Yocom and Denson (1962), and Johnson and Yocom (1966). No information exists on habitat use and ecological relationships of migratory birds on the lakes.

The purposes of this investigation were (i) to study the seasonal use of lake Earl and Lake Talawa by wetland birds, (ii) to determine habitat use, and (iii) to determine ecological relationships between birds and certain environmental conditions.

STUDY AREA

Lake Earl and Lake Talawa are coastal lagoons connected to each other by a narrow channel. The lakes are located 5 km north of Cresent City, Del Norte County, California and lie on a small, relatively flat coastal plain bordered by timbered mountains to the north, east, and south, and a coastal dune system to the west. Lake Earl is about 5.3 by 2.0 km and occupies about 731 ha when the water level is at mean high tide. Lake Talawa, located between Lake Earl and the Pacific Ocean, is about 2.2 by 0.4 km and occupies 64 ha. Both lakes vary from 0.5-3.0 m deep seasonally. Lake Earl has a mud substrate on its eastern side and a mud/sand substrate on its western side. The substrate of Lake Talawa is predominantly sand.

The sand barrier beach separating Lake Talawa from the ocean is usually lowered by a bulldozer to allow for drainage when high lake water during the winter rainy season floods surrounding lands. Although natural breaching occurs when a high lake water level and high tides cause the barrier beach to become saturated and wash away, flooding conditions during the study period were relieved by bulldozing before natural breaching could occur. Breaching by either means permits the discharge of lake water and the entry of seawater, resulting in a broad range of salinity. During the study, open water salinity of Lake Earl varied from 0.1-9.9 $^{0}/_{00}$, whereas salinity in Lake Talawa ranged from 2.3–27.8 $^{0}/_{00}$.

Lake Earl is characteristic of a freshwater or palustrine wetland. Dominant vegetation from the center of the lake shoreward consisted of sago pondweed, *Potamogeton pectinatus;* stonewort, *Chara* sp.; widgeon-grass, *Ruppia maritima;* at the juncture between Lake Earl and Lake Talawa, hardstem bulrush, *Scirpus acutus;* Olney's bulrush, *S. americanus*; broadleaf cattail, *Typha latifolia;* slough sedge, *Carex obnupta*; and common velvet grass, *Holcus lanatus.* Although Lake Talawa is usually closed to the Pacific ocean, it is basically an estuarine wetland. Dominant vegetation of Lake Talawa from the center of the lake shoreward consisted of widgeon-grass, stonewort, Olney's bulrush, Virginia glasswort, *Salicornia virginica;* seashore saltgrass, *Distichlis spicata;* and sweet vernal grass, *Anthoxanthum odoratum.*

METHODS

We conducted 66 bird counts from July 1974 through February 1976. Semi-weekly or weekly ground counts of birds on the entire lakes were conducted from 6 July 1974 to 20 September 1974 and 28 August to 19 December 1975. With one exception when two sequential counts were separated by three weeks, bi-weekly counts were conducted during the remaining periods. Lake Earl is too large to make one continuous count of all birds. Consequently, data were recorded from 16 separate lakeshore areas, established using existing landmarks. Using the 16 areas to count birds probably resulted in some duplicate counts of individual birds or in omission of others. The method, however, enabled a generally reliable count of species' seasonal abundance and composition. Observations of all birds on Lake Talawa, treated as one area, were made while walking along the lakeshore and infrequently from an outboard motorboat. Bird species, numbers, and habitat use, weather conditions, and date and hour were recorded at each area on every count. Birds at a distance were identified by use of 7X binoculars or a 20X spotting scope. Birds not identified to species were grouped, e.g., surface-feeding duck species, diving duck species, sandpiper species. Names of birds are from the American Ornithologist's Union (1983) and most recent supplements. Scientific and common names of plants are from Reed (1988)

Seven habitat types were described for Lake Earl and Lake Talawa: **Open Water** (795 ha)—sago pondweed, wigeon-grass, and stonewort; **Freshwater Marsh** (3 ha)—sago pondweed, common hornwort, *Ceratophyllum demersum,* whorled watermilfoil, *Myriophyllum verticillatum,* hardstem bulrush, and broad-leaf cattail; **Fresh/Brackish Marsh** (95 ha)—hardstem, Olney's and alkali bulrush, *Scirpus robustus,* and broad-lead cattail; **Salt Marsh** (66 ha)—Olney's bulrush, seashore saltgrass, and Virginia glasswort; **Flooded and Non-flooded Mud/Sandflats** (21 ha)—no vegetation; **Flooded and Non-flooded Pasture** (125 ha)—common velvet grass and sweet vernal grass; and **Sand Shore** (9 ha)—bare sandy shorelines up to European beachgrass, *Ammophila arenaria,* in landward dunes.

Relative preference of habitat types by wetland birds on Lake Earl and Lake Talawa was determined by use-availability analysis (Johnson 1980). The analysis was conducted on major groups of birds that clearly used a variety of habitat types but for which preference of use was not obvious. Diving ducks and other open-water birds (loons, grebes, Double-crested Cormorants, *Phalacrocorax auritus,* and Brown Pelicans, *Pelecanus occidentalis*) did not use a variety of habitats. Groups of birds were analyzed because data were sufficient, whereas data on individual species generally were not. Group analysis provides for a general picture of habitat preference and value. Four groups of birds were analyzed: surface-feeding waterfowl; herons, egrets, and American Bitterns, *Botaurus lentiginosus;* gulls and terns; and shorebirds. The American Coot, *Fulica americana,* was also analyzed because it was so numerous and used many habitats.

The use-availability analysis is based upon ranks of habitat types by use (number of birds observed) and by availability (area of habitat); the null hypothesis is that all habitat types were used equally. Preferred habitats are those for which use of the habitat ranked high but availability of the habitat ranked low. The difference between use rank and availability rank yields a measure of relative preference. For example, a use rank of 1 (i.e., most used habitat) minus an availability rank of 5 (i.e., fifth largest habitat area available) equals −4, indicating a high degree of preference over habitats where use ranked lower than availability. Habitats that received little or no use by a particular group of birds were deleted from the analysis. Statistical significance in all comparisons was determined by the method given by Johnson (1980).

Using the Statistical Analysis System (Barr et al. 1977), a bivariate correlation data analysis was conducted on the 36 most common bird species and four environmental factors: (i) total precipitation since the last count, (ii) mean temperature for the day of the observation, (iii) water level at 1200 hours on the day of the observation at the gauge nearest the bird observation area, and (iv) water salinity at the collection site nearest the bird observation area on the day of the observation or the day closest to it. The analysis included only those periods when birds were present. Correlation coefficient values (r) having an absolute value of ≥ 0.5 and supported at the 95% confidence interval were believed to indicate definite relationships between bird use and given environmental factors.

RESULTS AND DISCUSSION

Seasonal Species Abundance

Ninety-five wetland birds were studied, and results on seasonal abundance are presented for the 76 more common species (Table 1). Uncommon species (<10 individuals observed) were Pacific Loon, *Gavia pacifica,* Red-necked Grebe, *Podiceps grisegena,* Leach's Storm-Petrel, *Oceanodroma leucorhoa,* Pelagic Cormorant, *Phalacrocorax pelagicus,* Black Scoter, *Melanitta nigra,* Common Goldeneye, *Bucephala clangula,* Cattle Egret, *Bubulcus ibis,* Green-backed Heron, *Butorides striatus,* Black-crowned Night-Heron, *Nycticorax nycticorax,* Parastitic Jaeger, *Stercorarius parasiticus,* Glaucous Gull, *Larus hyperboreus,* Black Tern, *Chlidonias niger,* Black-necked Stilt, *Himantopus mexicanus,* Solitary Sandpiper, *Tringa solitaria,* Spotted Sandpiper, *Actitis macularia,* Ruddy Turnstone, *Arenaria interpres,* Baird's Sandpiper, *Calidris bairdii,* Wilson's Phalarope, *Phalaropus tricolor,* and Red Phalarope, *P. fulicaria.* Most birds used the lakes from late September through April (Figure 1). Bird numbers peaked during October, and high numbers also occurred during April (Figure 1). Overall, an annual average of 3,092,300 bird-use days was calculated where one bird-use day is one bird observed on one day. Comparison of our results on particular groups or species with other findings is discussed only when unusual differences occurred.

Waterfowl

Twenty-seven species of waterfowl were observed; the numbers recorded during the study exceeded 10 for 25 species (Table 1). Waterfowl use-days averaged 1,467,800 annually (surface-feeders—484,000; divers—983,000). Waterfowl were most common from October through January (Figure 2). Four species—the Ruddy Duck, *Oxyura jamaicensis,* Northern Pintail, *Anas acuta,* American Wigeon, *A. americana,* and Canvasback, *Aythya valisineria*—made up 80% of all waterfowl observed.

Tundra Swans, *Cygnus columbianus,* and geese were not common (Table 1). Peak numbers of swans were observed in December and January. Canada Geese, *Branta canadensis,* Greater White-fronted Geese, *Anser albifrons,* and Brant, *Branta bernicla,* occurred regularly but in small numbers (Table 1). Five subspecies of Canada geese were observed: Aleutian *B.c. leucopareia,* Cackling,

TABLE 1. Seasonal Abundance of Wetland Birds at Lakes Earl and Talawa, July 1974—February 1976.

	Season						
	*Summer74**	*Fall74*	*Winter 74/75*	*Spring75*	*Summer75*	*Fall75*	*Winter 75/76*
Species							
Waterfowl							
Tundra Swan (17)+		<1 ‡	87			13	65
Grt. White-fronted Goose (8)		1		<1		3	
Brant (22)	2	<1		2	<1		
Canada Goose (19)	<1	2	10	4	3	1	2
Swan/goose total	**2**	**3**	**97**	**6**	**3**	**17**	**67**
Wood Duck (29)	18	11			13	3	
Green-winged Teal (54)	17	159	116	112	40	178	362
Mallard (65)	199	151	50	41	83	48	32
Northern Pintail (62)	461	1,295	240	35	374	982	254
Blue-winged Teal (18)	4	1		2	2		<1
Cinnamon Teal (41)	5	8	20	91	5	<1	31
Teal species (36)	110	145			42	24	
Northern Shoveler (40)	4	60	7	3	7	29	4
Gadwall (66)	73	81	134	92	74	92	251
American Wigeon (58)	11	1,175	478	12	3	1,109	371
Surface-feeder species	90	16	30	3	37	30	17
Surface-feeder total	**994**	**3,105**	**1,172**	**397**	**683**	**2,512**	**1,389**
Canvasback (53)	1	317	1,193	99	4	552	1,425
Redhead (14)		<1	2	2		<1	1
Ring-necked Duck (32)	<1	15	23	<1		22	21
Greater Scaup (65)	354	301	8	126	115	165	13
Oldsquaw (11)	<1	<1				<1	
Surf Scoter (16)	<1		1	113	<1	<1	1
White-winged Scoter (13)		<1	2	11			<1
Bufflehead (62)	6	27	83	186	5	40	146
Hooded Merganser (22)	<1	<1		<1	5	<1	2
Common Merganser (9)					1	2	<1
Red-breasted Merganser (32)	18	25		<1		<1	1
Ruddy Duck (65)	18	2,188	2,046	687	25	3,129	4,206
Diving duck species (14)	<1	9	<1	<1		20	<1
Diving duck total	**397**	**2882**	**3,258**	**1,224**	**155**	**3,930**	**5,816**
Waterfowl total	**1,391**	**5,987**	**4,530**	**1,621**	**838**	**6,442**	**7,205**
Other Wetland Birds							
Red-throated Loon (18)			2	1		<1	8
Common Loon (57)	4	2	3	3	4	1	2
Pied-billed Grebe (66)	233	341	67	20	162	259	74
Horned Grebe (42)		39	95	138	<1	49	166
Eared Grebe (38)		10	47	58		14	100
Western Grebe (66)	114	101	84	89	113	96	81
Grebe species	<1	8	9	13	<1	1	4
Brown Pelican (15)	3	9			<1	<1	
Dbl.-crested Cormorant (66)	36	41	51	55	15	20	30
Non-waterfowl diver total	**390**	**551**	**359**	**377**	**294**	**440**	**465**
American Bittern (49)	4	11	2	1	1	2	<1
Great Blue Heron (65)	10	15	13	6	7	9	8
Great Egret (62)	21	34	35	7	4	20	25
Snowy Egret (12)	<1		<1	<1	<1	<1	2
Heron/egret/bittern total	**35**	**60**	**50**	**14**	**12**	**31**	**35**
Northern Harrier (64)	4	9	12	4	1	4	6
Virginia Rail (50)	1	10	2	2	2	4	2
Sora (14)	<1	2	<1			<1	
American Coot (65)	46	4,450	3,516	1,383	188	5,305	2,469
Bonaparte's Gull (43)	7	10		32	47	11	<1
Heermann's Gull (25)	20	40			11	4	
Mew Gull (7)			<1	<1			6
Ring-billed Gull (47)	19	85	18	2	11	10	<1
California Gull (26)	2	9	83	5	6	22	<1
Herring Gull (10)				2		<1	4
Western Gull (63)	330	527	207	307	227	717	384
Glaucous-winged Gull (20)		<1	2	129	<1	<1	16

(Continued)

TABLE 1. —Continued.

	Season						
	*Summer74**	*Fall74*	*Winter 74/75*	*Spring75*	*Summer75*	*Fall75*	*Winter 75/76*
Gull species	28	17	174	37	14	6	29
Caspian Tern (4)	<1	3		1	<1	<1	
Common Tern (8)	<1	14		<1		<1	
Gull/tern total	**406**	**705**	**484**	**515**	**366**	**770**	**439**
Belter Kingfisher (35)	1	2	1		1	1	1
Other wetland bird total	**883**	**5,791**	**4,424**	**2,295**	**864**	**6,555**	**3,417**
Shorebirds							
Black-bellied Plover (40)	<1	6	3	4	3	7	5
Lesser Golden-Plover (5)		<1				1	
Snowy Plover (22)	2			1	1	1	
Semipalmated Plover (33)	4	3		5	32	11	<1
Killdeer (61)	9	31	82	20	14	33	65
American Avocet (14)	1	4		<1		<1	
Greater Yellowlegs (57)	7	13	10	33	4	8	13
Lesser Yellowlegs (23)	3	12			2	3	
Willet (18)	3	4		<1	1	<1	
Wimbrel (18)	<1	2		30	7	2	
Long-billed Curlew (10)	<1	1		2		<1	
Marbled Godwit (27)	42	29	<1	1	23	56	
Black Turnstone (19)	<1	1	5	1	<1	<1	1
Red Knot (14)	1	4		<1	2	1	
Sanderling (26)		<1	118	102		19	88
Western Sandpiper (58)	178	409	<1	559	358	405	36
Least Sandpiper (57)	65	115	166	334	19	44	263
Pectoral Sandpiper (12)		1			<1	4	
Dunlin (44)	<1	123	422	521	4	164	733
Stilt Sandpiper (6)	<1	<1				<1	<1
S.b./L.b. Dowitchers (59)	147	183	27	121	89	239	61
Common Snipe (43)	<1	40	28	17		16	32
Red-necked Phalarope (28)	54	36		3	12	66	
Shorebird species	155	34	60	38	14	16	6
Shorebird total	**671**	**1,051**	**921**	**1,792**	**585**	**1,096**	**1,303**
GRAND TOTAL	**2,945**	**12,829**	**9,875**	**5,708**	**2,287**	**14,093**	**11,925**

*Summer = July–Aug. 1974 and June–Aug. 1975 in which 15 counts were taken; Fall = Sept.–Nov.—24 counts; Winter = Dec.–Feb.—14 counts; and Spring = Mar.–June 1975 only—7 counts.

+ Number of counts in which species was seen during the study period.

‡ Average number of birds/count/season.

B.c. minima, Dusky, *B.c. occidentalis,* Great Basin, *B.c. moffitti,* and Taverner's *B.c. taverneri.* Thirty-five Aleutian Canada Geese, listed as endangered by the U.S. Fish and Wildlife Service (1987), were noted on October 27, 1975. A peak of 4,700 of these birds was observed in pastures adjoining Lake Earl, 29 March 1988 (Robert McNab, pers. comm.). Closure of several areas in California to Canada Goose hunting and reestablishment of nesting on several of the Aleutian Islands have resulted in an increase in the population. We did not record any breeding geese, but Hehnke (op. cit. p.85) reported a Dusky or Vancouver Canada Goose, *B. c. fulva,* with three downy goslings at Lake Talawa. Probably this was a cripple as the Dusky subspecies breeds in Alaska, but we have noted a few in the Lake Earl area in the winter.The Vancouver subspecies breeds south only to coastal British Columbia and is largely nonmigratory (Hansen and Nelson 1964).

Surface-feeding ducks were most common in fall. Highest concentrations occurred from August through December (Figure 2). Of the nine species recorded, the Northern Pintail and American Wigeon were the most abundant (Table 1). The Gadwall, *Anas strepera*, and Mallard, *A. platyrhynchos,* occurred year-round. Other species that regularly occurred in smaller numbers were

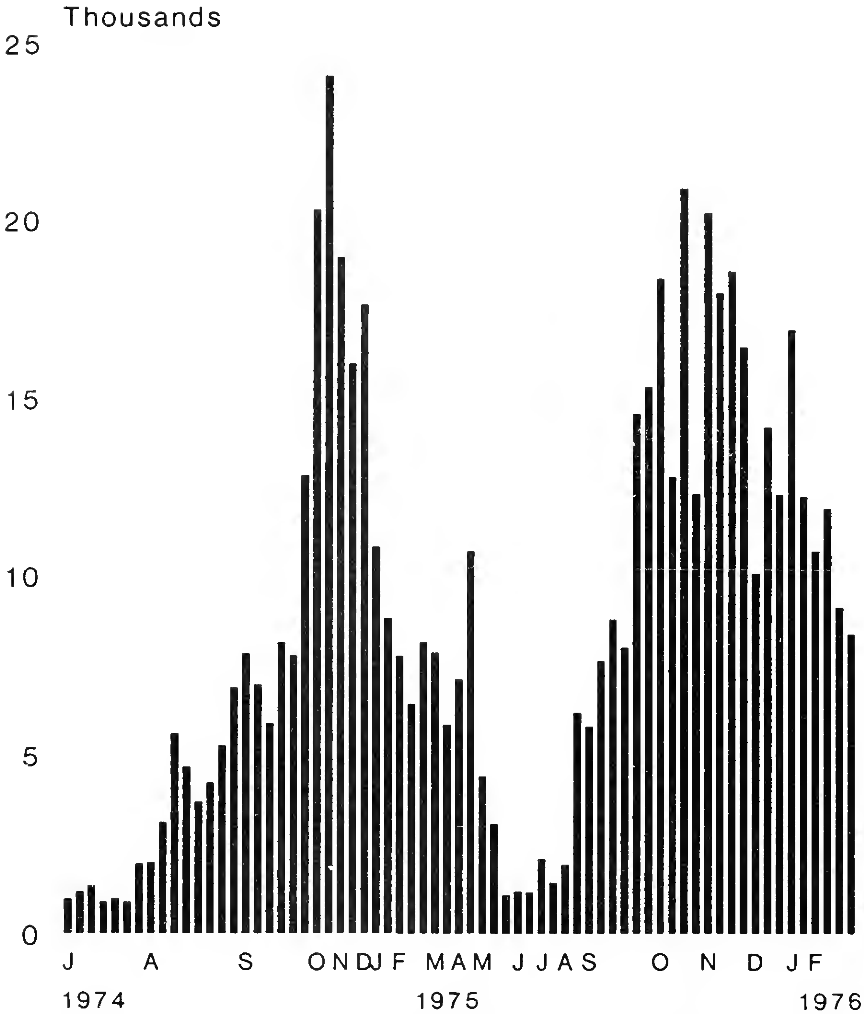

FIGURE 1. Seasonal abundance of wetland birds on lake Earl and Lake Talawa, July 1974–February 1976.

Wood Duck, *Aix sponsa,* Green-winged Teal, *Anas crecca,* Blue-winged Teal, *A. discors,* Cinnamon Teal, *A. cyanoptera,* and Northern Shoveler, *A. clypeata* (Table 1). Our average Gadwall numbers were 73–74 per census in the summer; however, Hehnke (op. cit. p.85) reported 660 in late August 1969. Peters (op. cit. p.85) observed no Blue-winged Teal or Wood Ducks and only one northern Shoveler during his 1970–71 study. Breeding species in our study in descending order of abundance were Gadwall, Mallard, Cinnamon Teal, Wood Duck, and Blue-winged Teal. Johnson and Yocom (1966) reported the Gadwall to be the least abundant breeding duck, but our results show that the species has apparently increased its breeding population on the study area.

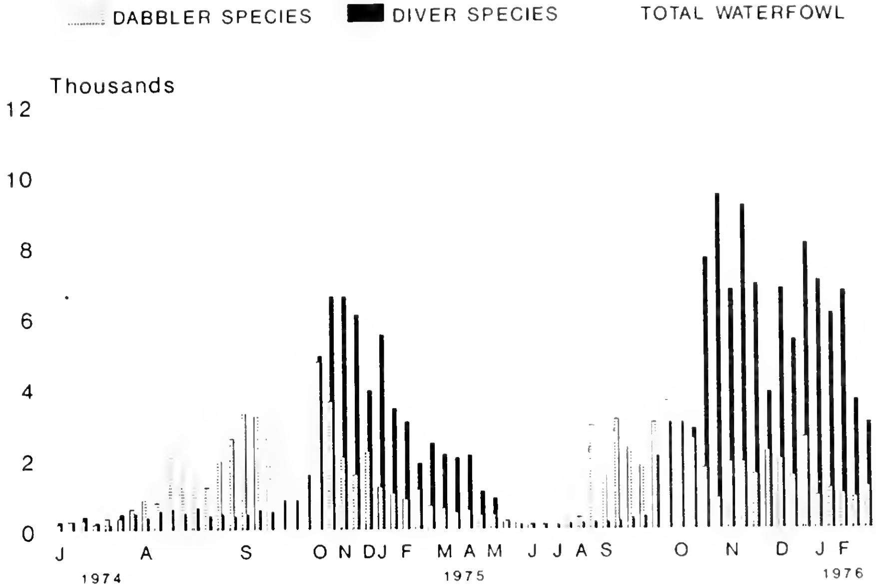

FIGURE 2. Seasonal abundance of waterfowl on Lake Earl and Lake Talawa, July 1974–February 1976.

Highest concentrations of diving ducks occurred from October through January (Figure 2). Fourteen species were seen; the numbers noted during the study were >10 for 12 species (Table 1). The Ruddy Duck was the most numerous of all waterfowl recorded. The Canvasback was the second most abundant diving duck and fourth most abundant waterfowl species (Table 1). Peters (op. cit. p.1) observed a high of 1,400 Ruddy Ducks, but we observed a high of 7,600. The highest number of Canvasbacks noted by Peters (op. cit. p.85) was 900, whereas we observed a peak of 2,700. We never saw more than four Redheads, *Aythya americana,* at one time, but Dan Scott (Calif. Dept. of Parks and Recreation, pers. comm.) reported 127 in December 1984. Our results on Redheads do not agree with Yocum and Denson (1962) who state that this species is found in large numbers on Lake Earl. Our findings show the Greater Scaup, *A. Marila,* to be a common summer visitant and not rare as given by Yocom and Harris (1975). Species that regularly occurred but in small numbers were the Ring-necked Duck, *A. collaris,* Oldsquaw, *Clangula hyemalis,* Surf Scoter, *Melanitta perspicillata,* White-winged Scoter, *M. fusca,* Bufflehead, *Bucephala albeola,* Hooded Merganser, *Mergus cucullatus,* Common Merganser, *M. merganser,* and Red-breasted Merganser, *M. serrator* (Table 1). The Ruddy Duck was the only nesting diving duck recorded. A female and four downy young were seen on Lake Earl on 13 and 17 September 1974, the first breeding record for the area; other breeding records have been obtained since. Hehnke (op cit. p.85) reported three Common Merganser broods in his summer 1969 study, but none have been recorded since. A Ring-necked brood was observed on 19 July 1984 (Dan Scott, pers. comm.), followed by others subsequently, and a Redhead brood was reported on 14 June 1984 (Richard Erickson, pers. comm.).

Other Wetland Birds

Thirty-seven species of wetland birds other than waterfowl and shorebirds (e.g., herons and gulls) were observed. The numbers recorded during the study exceeded 10 for 27 species (Table 1). The average number of bird use-days per year was 1,203,600. The American Coot was the most abundant bird of any group found within the study area; peak numbers (∾12,000) were noted during the fall (Figure 3). Species of other wetland birds commonly seen during the study area were the Western Gull, *Laurus occidentalis,* Pied-billed Grebe, *Podilymbus podiceps,* Western Grebe, *Aechmophorus occidentalis,* Horned Grebe, *Podiceps auritus,* Glaucous-winged Gull, *Larus glaucescens,* Eared Grebe, *Podiceps nigricollis,* and Double-crested Cormorant (Table 1). The Northern Harrier, *Circus cyaneus,* was the most common raptor observed (Table 1). Species that occurred regularly but in small numbers were Red-throated Loons, *Gavia stellata,* Common Loon, *G. immer,* American bittern, Great Blue Heron, *Ardea herodias,* Great Egret, *Casmerodius albus,* Snowy Egret, *Egretta thula,* Virginia Rail, *Rallus limicola,* Sora, *Porzana carolina,* Bonaparte's Gull, *Larus philadelphia,* Heermann's Gull, *L. heermanni,* Mew Gull, *L. canus,* Ring-billed Gull, *L. delawarensis,* California Gull, *L. Californicus,* Herring Gull, *L. argentatus,* Caspian Tern *Sterna caspia,* Common Tern, *S. hirundo,* and Belted Kingfisher, *Ceryle alcyon* (Table 1).

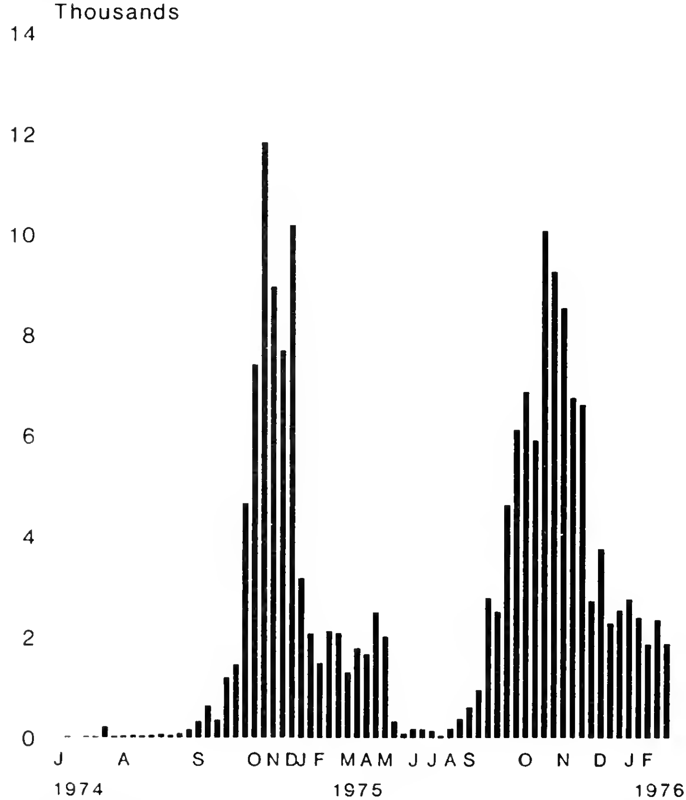

FIGURE 3. Seasonal abundance of American Coot on Lake Earl and Lake Talawa, July 1974–February 1976.

Our findings on Horned and Eared Grebes were much higher (> 100) than the numbers (< 15) observed by Peters (op. cit.). Hehnke (op. cit.) and Peters (op. cit.) observed fewer (1–60) Pied-billed Grebes than we did (~300). Our findings on this species also differ from Yocom and Harris (1975) who considered the species to be an uncommon resident. The highest number of Brown Pelicans we saw was 38, but Widrig (Widrig. R.S. 1977. Spring nesting and fall migration observations of shorebirds at Lake Talawa, Del Norte County, California. Unpubl. rep. on file Humboldt State Univ. Library, Arcata, CA. 6 p. plus appendices) observed 100 on one occasion. Hehnke (op. cit.) and Peters (op. cit. p.85) recorded substantially lower numbers of Western Gulls than we did; our higher numbers may have resulted from this species' attraction to seafood refuse spread on pastures adjacent to Lake Talawa by a rancher. In contrast to our findings, Peters (op. cit.) never observed more than four Bonaparte's Gulls.

During summer 1974, coot broods were observed seven times and Pied-billed Grebe broods were observed 28 times. A previously unconfirmed nesting colony of over 40 pairs of Western Grebes was noted on the northeastern section of Lake Earl near a large stand of hardstem bulrush.

Shorebirds

Of the 31 species of shorebirds seen, the numbers noted during the study were > 10 for 24 species (Table 1). The average annual number of bird-use days was 421,600. Highest numbers were seen during April (Figure 4). The principal species in our study, the Western Sandpiper, *Calidris mauri,* Dunlin, *C. alpina,* Least Sandpiper, *C. minutilla,* Long-billed Dowitchers, *Limodromus scolopaceus,* and Short-billed Dowitchers, *L. griseus,* made up 79% of the total number of shorebirds. These species were also the most abundant birds noted at Bolinas Lagoon, California from 1971–76 (Page and Stenzel 1975). Species regularly seen in small numbers were the Black-bellied Plover, *Pluvialis squatarola,* Lesser Golden-Plover, *P. dominica,* Snowy Plover, *Charadrius alexandrinus,* Semipalmated Plover, *C. semipalmatus,* Killdeer, *C. vociferus,* American Avocet, *Recurvirostra americana,* Greater Yellowlegs, *Tringa melanoleuca,* Lesser Yellowlegs, *T. flavipes,* Willet, *Catoptrophorus semipalmatus,* Long-billed Curlew, *Numenius americanus,* Whimbrel, *N. phaeopus,* Marbled Godwit, *Limosa fedoa,* Black Turnstone, *Arenaria melanocephala,* Red Knot, *Calidris canutus,* Sanderling, *C. alba,* Pectoral Sandpiper, *C. melanotos,* Stilt Sandpiper, *C. himantopus,* Common Snipe, *Gallinago gallinago,* and Red-necked Phalarope, *Lobipes lobatus* (Table 1).

Hehnke (op. cit.) and Peters (op. cit.) generally saw fewer shorebirds than we did, whereas Widrig (op. cit.) recorded more black-bellied Plovers, Ruddy turnstones, and Lesser Yellowlegs than we. We observed no Upland Sandpipers, *Bartramia longicauda,* or Wandering Tattlers, *Heteroscelus incanus;* however, one individual of the former species was observed on Lake Talawa by William Marshall (pers. comm.) on 13 September 1976 and single birds of the latter species were seen by Widrig (op. cit.) on 26 August 1977, and by Richard Erickson (pers. comm.) on 16 July 1981. Widrig (op. cit. p.85) did not see any Willets during his study. The highest number of Red Knots we saw was 12, but Widrig (op. cit.) recorded 46. Although we recorded no Sharp-tailed

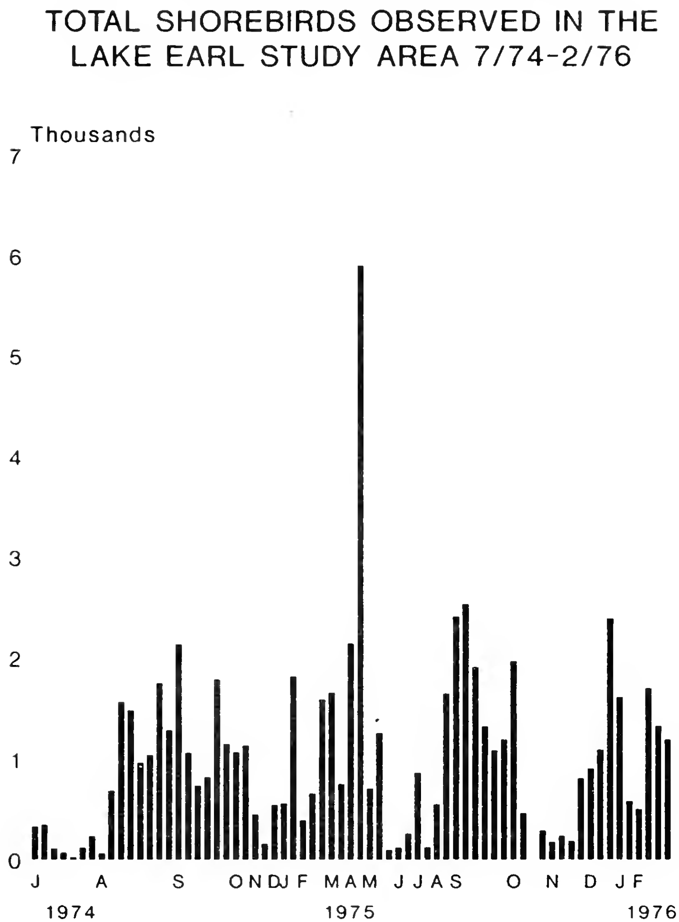

FIGURE 4. Seasonal abundance of shorebirds on Lake Earl and Lake Talawa, July 1974–February 1976.

Sandpipers, *Calidris acuminata,* Widrig (op. cit.) recorded two to three individuals on Lake Talawa on four occasions. Widrig (op. cit.) saw many more Baird's Sandpipers than we did and recorded several hundred more Least Sandpipers in the fall than we. Peak numbers (2,825) of Western Sandpipers in the fall noted by Widrig (op. cit.) exceeded our fall peak of over 1,000 birds. Hehnke's (op. cit. p.1) counts of 1,300 to 2,100 Western Sandpipers in summer and early fall were also higher than our counts for the same seasons. No Hudsonian godwits, *Limosa haemastica,* or Ruffs, *Philomachus pugnax,* were noted by us, but Widrig (op. cit.) saw one of each on Lake Talawa on 12 September 1977. We did not record any breeding of shorebirds but suspected a nest of Snowy Plovers on Lake Talawa during spring 1976. Widrig (op. cit.), however, was successful in recording the breeding of Snowy Plovers, Killdeers, and a Wilson's Phalarope.

Habitat Use

Data were summarized on habitat use of 73 species of wetland birds (Table 2). Twelve species, eight of which were surface-feeding ducks, were observed in six or more of the seven available habitats. The other birds used one to five habitats.

TABLE 2. Percentage of Annual Habitat Use by Total Number of Wetland Birds at Lakes Earl and Talawa.

	Habitat types						
Species	*Open water*	*Fresh/ brackish marsh*	*Salt marsh*	*Mud/ sand flats*	*Pasture*	*Fresh-water*	*Sand shore*
Waterfowl							
Tundra Swan	32	<1	1	55	12		
Grt. White-fronted Goose				27	73		
Brant	24	5	5	24	5		37
Canada Goose	19	5			76		
Swan/goose total	**29**	**1**	**1**	**45**	**22**		**2**
Wood Duck	76	12		2		10	
Green-winged Teal	36	5	3	22	32	1	1
Mallard	45	29	4	15	4	3	
Northern Pintail	84	1	2	9	3	1	<1
Blue-winged Teal	28	14	2	20	16	20	
Cinnamon Teal	5	10	14	20	50	1	
Teal species	36	18		27	11	8	
Northern Shoveler	52	3	2	16	25	2	<1
Gadwall	63	3	14	8	2	10	
American Wigeon	92	1	1	2	1	3	<1
Surface-feeding species	58	11	7	19	1	5	
Surface-feeder total	**75**	**4**	**3**	**9**	**6**	**3**	**<1**
Canvasback	100					<1	
Redhead	74			26			
Ring-necked Duck	96					4	
Greater Scaup	100			<1		<1	
Oldsquaw	71			8			21
Surf Scoter	100					<1	
White-winged Scoter	100						
Bufflehead	99		1			<1	
Hooded Merganser	80			16		4	
Common Merganser	66	11		23			
Red-breasted Merganser	98		1	1			
Ruddy Duck	100	<1				<1	
Diving duck species	100					<1	
Diver duck total	**99**	**<1**	**<1**	**<1**		**<1**	**<1**
Waterfowl total	**90**	**2**	**1**	**4**	**2**	**1**	**<1**
Other Wetland Birds							
Red-throated Loon	100						
Common Loon	100						
Pied-billed Grebe	100		<1		<1	<1	
Horned Grebe	100	<1	<1			<1	
Eared Grebe	100		<1				
Western Grebe	100	<1				<1	
Brown Pelican	32						68
Dbl.-crested Cormorant	99			1		<1	
Non-waterfowl diver total	**99**	**<1**	**<1**	**<1**	**<1**	**<1**	
American Bittern		88	12				
Great Blue Heron		31	11	35	13	<1	10
Great Egret		29	22	31	17		1
Heron/egret/bittern total		**33**	**19**	**29**	**15**	**<1**	**4**
Northern Harrier		75	10	1	13		<1
Virginia Rail		100					
Sora Rail		100					
American Coot	77	1	<1	3	17	2	
Bonaparte's Gull	26		20	32	<1		22
Heerman's Gull			<1				100
New Gull	13			12			75

Ring-billed Gull	52	<1	<1	34	<1		13
California Gull	39			21	6		34
Herring Gull	3			48			49
Western Gull	7		<1	32	16		45
Glaucous-winged Gull	1			1	5		93
Gull species	**16**			**16**	**6**		**62**
Caspian Tern	12			74			14
Common Tern	55	4	3	19			19
Gull/tern total	**12**	**<1**	**<1**	**15**	**15**		**58**
Other wetland bird species	14			7	10		59
Shorebirds							
Black-bellied Plover			26	40	5		29
Lesser Golden-Plover			6	13	50		31
Snowy Plover				5	2		93
Semipalmated Plover			7	68	<1		25
Killdeer		<1	5	21	69		5
American Avocet				79			21
Greater Yellowlegs			22	49	29		<1
Lesser Yellowlegs			1	95			4
Willet				47			53
Whimbrel			80	16	3		1
Marbled Godwit			4	90	<1		6
Black Turnstone				40			60
Red Knot				57		43	
Sanderling			15	62	<1		23
Western Sandpiper		<1	26	57	6		11
Least Sandpiper		<1	30	43	22		5
Pectoral Sandpiper		22		73	5		
Dunlin			20	45	26		9
Stilt Sandpiper				90	10		
S.b./L/b. Dowitchers		<1	22	63	9		6
Common Snipe		21	5	19	55		
Red-necked Phalarope	92		3	5		<1	
Shorebird species			4	86	1		9
Shorebird total	**1**	**<1**	**22**	**52**	**15**		**9**
GRAND TOTAL	**69**	**1**	**4**	**11**	**9**	**1**	**4**

In decreasing order, habitats used most were open water (69%), flooded and non-flooded mud/sandflat (11%), flooded and non-flooded pasture (9%), sand shore and salt marsh (4% each), and freshwater marsh and fresh/brackish marsh (1% each) (Table 2). Results of the habitat use vs. availability analysis showed that freshwater marsh, mud/sandflat, and sand shore were generally preferred over other habitat types by the four groups of birds (surface-feeding waterfowl; herons, egrets, and bitterns; gulls and terns; and shorebirds) and American coot that were analyzed (Figure 5). The principal areas of use of all species of waterfowl (except Cinnamon Teal) on Lake Earl and Lake Talawa were deep and shallow open water. Food analysis by Rodiack (Rodiack, J. C. 1976. Fall and winter flood habits of ducks at Lake Earl. Unpubl. rep., Wildl. Dept., Humboldt State Univ., Arcata, CA. 4 p. plus figures and tables) showed that sago pondweed was the most important food item for waterfowl in this part of the lake.

Surface-feeding ducks used all available habitats but relied primarily on open water (75%) and secondarily on mud/sandflats (9%). Habitat preference analysis (Figure 5) indicated that surface-feeding ducks showed significantly higher preference for freshwater marsh and mud/sandflat habitats than for the other habitats used by this group. The American Wigeon and Northern Pintail used open water predominantly (92% and 84%, respectively). The Tundra Swan, Green-winged Teal, and Blue-winged Teal frequently used this habitat as well as shallow water mud or sandflats and pastures; most Cinnamon Teal used the last two types of habitat. Marshall (1953) determined that the American Wigeon was the second most abundant species of waterfowl on open water at Mission Bay, California. Romero (1976) found that surface-feeding waterfowl on Anaheim Bay, California, generally used tidal channels and mudflats.

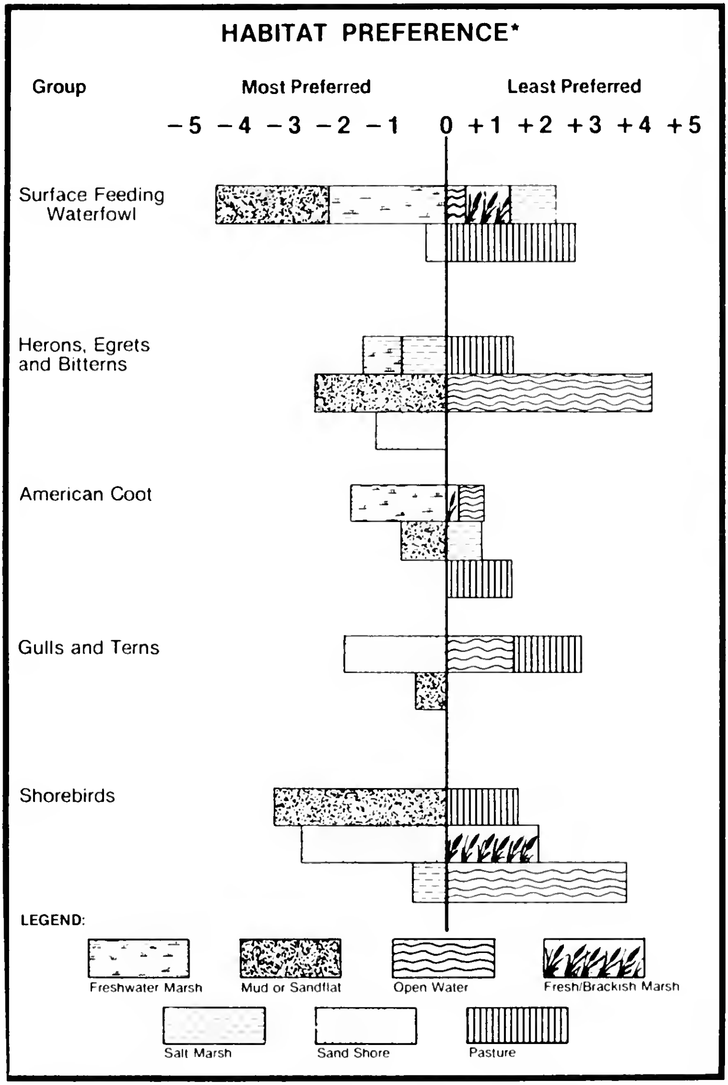

FIGURE 5. Bird use vs. habitat availability (* habitats shown for each group were the only ones the groups were observed in). Joined habitat types show no significant difference in preference between or among these habitats. Values show average difference between ranks of habitat type vs. availability; negative values show preference, positive show no preference.

All diving ducks recorded on Lake Earl and Lake Talawa used open water to a high degree (Table 2). The Canvasback, Greater Scaup, White-winged Scoter, Surf Scoter, and Ruddy Duck used open water almost exclusively. Almost all of the remaining species of diving ducks used other habitats to some extent, although they made primary use of open water. Buffleheads and Surf Scoters were recorded in large numbers on open water at Mission Bay, California (Marshall 1953).

Loons, grebes, and cormorants used open water almost exclusively in every count (Table 2). The Horned, Pied-billed, and Eared Grebe were found commonly on open water at Mission Bay, California (Marshall 1953). Western Grebes used tidal channels and flooded mudflats on Anaheim Bay, California (Romero 1976). At Lake Talawa the Brown Pelican was seen mostly on sand shore where they loafed; they used open water to a lesser extent (Table 2). Marshall (1953) and Romero (1976) found that Brown Pelicans used open water most at Mission Bay and Anaheim Bay, California, respectively.

Highest numbers and densities of gulls and terns were found on sand shore and mud/sandflat, mostly on Lake Talawa (Table 2). These habitat types were also preferred over open water and pasture (Figure 5). Gulls and terns favored beach, land fill, and mudflat on Anaheim Bay, California (Romero 1976). At Mission Bay, California, Ring-billed Gulls were abundant on sand shores, and Western Gulls were common in this habitat and in open water (Marshall 1953).

As a group, herons, egrets and bitterns preferred mud/sandflat primarily and sand shore secondarily (Table 2). The most common species within this group, the Great Egret and Great Blue Heron, used mud/sandflats, fresh/brackish marsh, pastures, and salt marsh most heavily (Table 2). These two species were common on sand shore at Mission Bay, California (Marshall 1953). Most American Bitterns frequented fresh/brackish marsh containing moderately high to tall (0.5–2.0 m) vegetation.

Virginia and Sora Rails were seen only in fresh/brackish marsh. The American Coot used open water 77% of the time and flooded pasture 17% of the time (Table 2). The only habitat not used by coots was sand shore. Habitat use vs. availability analysis indicates that the coot preferred freshwater marsh predominantly and mud/sandflat secondarily (Figure 5).

Overall, shorebirds used mud/sandflat over twice as much as any other habitat type, followed by salt marsh, pasture, and sand shore (Table 2). Mud/sandflat was also more preferred by this group whereas sand shore was second in preference (Figure 5). Marshall (1953), Page and Stenzel (Page, G., and L. E. Stenzel. 1975. Aspects of the ecology of shorebirds on Bolinas Lagoon. Dept. of Parks and Recre., Co. of Marin, CA. 89 p.) and Romero (1976) also found that shorebirds favored mud/sandflat along coastal California.

The Marsh Hawk used fresh/brackish marsh 75% of the time. Less frequently used habitats were pasture and salt marsh (Table 2).

Correlation Analysis of Bird Use vs. Environmental Factors

Bivariate correlation analysis showed no significant correlations between numbers of individual species and the four environmental factors studied (rainfall, temperature, water level, and salinity). Rapid changes in salinity and water level due to breaching the barrier beach, and occurrence of both high and low numbers of migrating birds at both high or low water level periods may have accounted for the lack of correlations. Counts may not have been conducted frequently enough to adequately determine existing correlations. Page, Stenzel and Wolfe (1979) remarked that difficulties can be expected in determining factors affecting shorebird numbers because entire rather than parts of estuarine habitat complexes must be evaluated. Probably, daily changes in shorebird numbers on Lake Earl and Lake Talawa were also influenced by the large numbers of tidal mudflat and sandflat that became available during low tide at the nearby Smith River delta and Crescent City harbor. Many species were not affected by slight to moderate seasonal changes in the physical environment of Lake Earl and Lake Talawa because the changes did not disrupt the availability of the habitats they used.

Observations indicated, however, that shorebirds, especially migrating and wintering individuals, occurred in large numbers when mudflats and sandflats were exposed. This was dramatically illustrated when breaching of the barrier beach allowed Lake Talawa to drain rapidly, making additional flats available to birds for varying periods of time. Widrig (op. cit. p.11) noted the same response. Three species, the Least Sandpiper, Dunlin, and Western Sandpiper, seemed to be most directly influenced by the drastic changes in the water level. The Green-winged Teal, Cinnamon Teal, American Coot, Greater Yellowlegs, Western Sandpiper, Dunlin, and the dowitchers, used pasture and mud/sandflat considerably more in winter and spring when these areas were flooded than at other times of the year. Gerstenburg (1972) noted that upland areas around Humboldt Bay, California, were used by shorebirds mostly during rainy periods.

Even though seasonal changes in salinity showed no significant statistical correlation with changes in bird numbers, the degree of salinity and its effect on the types and amount of habitat generally determined the overall distribution of many birds on Lake Earl and Lake Talawa.

CONCLUSIONS AND RECOMMENDATIONS

Findings of this study show that Lake Earl and Lake Talawa serve as an important wetland area for a wide variety of migrating and wintering species of wetland birds. Three key elements are believed to be responsible for the heavy use of the lakes by wetland birds. First, the Lake Earl and Lake Talawa ecosystems provide a variety of habitats used by migrating birds. These habitats provide useful cover and contain valuable food items, especially sago pond-weed, widgeon-grass, and a variety of arthropods and fish. Second, because these lakes are located on the Pacific coast, they lie in the direct path of millions of migrating birds. Such a location, combined with the available habitat and food resources at the lakes, promotes heavy and extensive use by wetland birds. Third, the lakes are not heavily used by hunters during the hunting season. Consequently, human disturbance is minimized, and birds using the area are not pressured to move elsewhere.

Like most wetlands, Lake Earl and Lake Talawa are vulnerable to human activities and developments. Fortunately, the lakes were purchased by the State of California and made part of its park and wildlife area systems. We believe the lakes should remain in public ownership so that they can be preserved indefinitely for migrating birds. Efforts should be made to manage human use of the area so birds will continue to use this wetland in numbers similar to or greater than those found in this study. The seasonal entry of ocean water into the lakes exerts a profound favorable influence on the extent and variety of habitat and food types used by migrating birds. We recommend that the introduction of seawater be allowed to continue when winter flooding conditions exist so that the unique ecology of the lakes is maintained.

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LIFE HISTORY OF THE SEVENGILL SHARK, *NOTORYNCHUS CEPEDIANUS* PERON, IN TWO NORTHERN CALIFORNIA BAYS [1]

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Life history information was gathered on 128 sevengill sharks, *Notorynchus cepedianus,* from the coastal waters of California during a 20 month period from November 1981 through June 1983. The majority of sevengill sharks (96) were collected during the spring and summer in Humboldt and San Francisco bays. Gonad characteristics, egg size, embryo development, and scarring in adult sevengills captured in bays suggest a spring-summer breeding season. Cartilaginous and bony fishes were the major prey items of sevengill sharks captured in these bays. A distinct background color was observed for sevengills from different geographic regions. Several age determination techniques using vertebrae were tested. The ecosystem of several northern California bays plays an important role in the life history of the sevengill shark.

INTRODUCTION

Interest in elasmobranchs as a food resource has increased in California and among the more commonly marketed species is the sevengill shark, *Notorynchus cepedianus* Peron, 1807. This shark is known to frequent bays, including Humboldt and San Francisco bays where they support a small commercial fishery and are a popular target species of sportfishermen (Figure 1). Unfortunately, the elasmobranch assemblage of these bays is poorly understood and the importance of larger sharks, like the sevengill, to the bay environment is not well known.

The sevengill shark is a member of the family Hexanchidae (cowsharks), which Compagno (1981) lists as having three genera and four or five living species. World-wide, several nominal species of the genus *Notorynchus* (Ayres, 1855) have been described, with *N. maculatus* as the species representative from the eastern North Pacific. The distinguishing characteristic in these nominal species stem from the number of medial teeth (1 to 4) on the symphysis of the upper jaw (Kemp 1978). This difference is usually attributed to individual variation rather than as a distinctive characteristic (Bass, D'Aubrey, and Kistnasamy 1975, Kemp 1978, and Compagno 1984). Therefore, most recent authors have synonymized *Notorynchus* as a single species, *N. cepedianus.* Subsequent work I have conducted on this species confirms these author's opinion that *Notorynchus* is a monotypic genus.

Notorynchus cepedianus is found predominantly in the temperate waters of both hemispheres, with no confirmed record of it from the tropics. In the eastern North Pacific sevengill sharks range form southeastern Alaska to the Gulf of California, with their distribution becoming sporadic south of San Francisco Bay.

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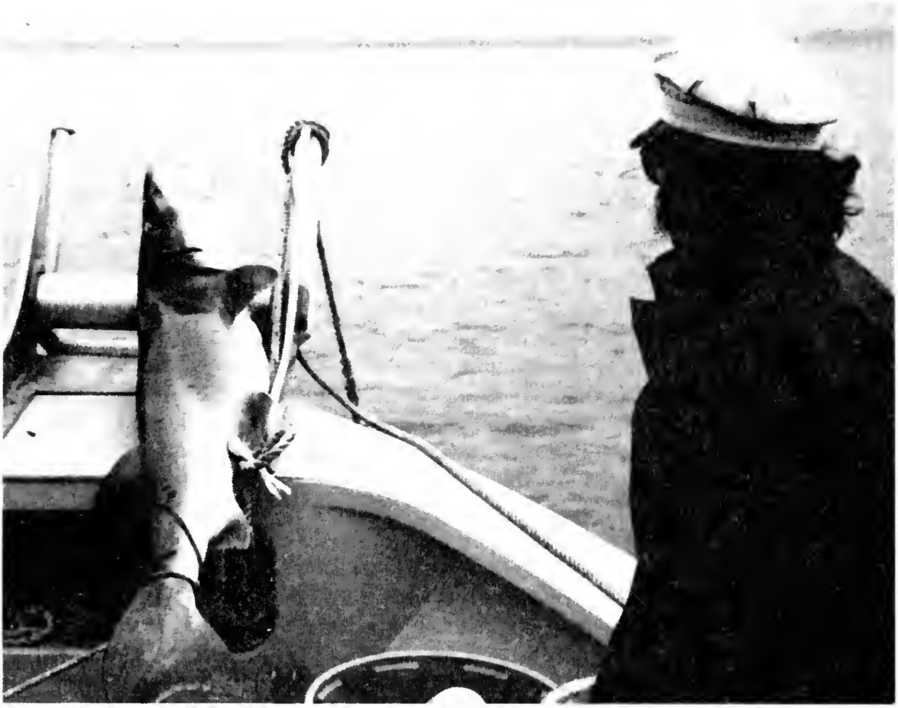

FIGURE 1. Commercial shark fisherman bringing aboard a 242 cm TL sevengill. Photograph by author.

Since many elasmobranch species including the sevengill shark are mobile and reach a relatively large size, life history studies have been difficult. Members of the Hexanchidae are ovoviviparous (Gilbert 1981), but further information on their reproductive biology is limited. Herald and Ripley (1951) examined a number of sevengill sharks between 54 and 228 cm TL caught at shark derbies and reported that all sevengills examined were sexually immature. Herald (1961) estimated that sevengills reached maturity at a length of 306 cm TL. However, Herald (1968) revised this estimate after examination of a male (197.4 cm TL) and female (264 cm TL) sevengill that were both mature.

Information on the feeding habits of the sevengill shark is rather incomplete. Hart (1973) reported that the sevengill's diet included smaller sharks. Herald and Ripley (1951) examined a few sevengill shark stomachs and found them to be either empty or to contain only bait.

The objectives of this research were to investigate the life history of the sevengill shark in two northern California bays; this includes reproductive biology, length-weight relationships, food habits, age determination techniques, color variation, parasites, and movement patterns along the California coast.

MATERIALS AND METHODS

Sevengill shark data were obtained from field samples and reference collections. Most sevengill data were obtained from field collections made in Humboldt Bay (lat 40° 52′ N) and San Francisco Bay (lat 37° 42′ N). Additional data were obtained from the California Academy of Sciences, Moss Landing

Marine Laboratories, Natural History Museum of Los Angeles County, and the Tiburon Center for Environmental Studies.

Shark samples were collected by several methods, including gill net, harpoon, long-line, and rod-and-reel. Sevengills in Humboldt Bay were captured using a gill net or harpooned during the spring and summer. Shark fishing in San Francisco Bay was conducted year-round using long-line gear and rod-and-reel. Gill nets were used in San Francisco Bay only during winter months.

Measurements of shark alternate length (AL, distance between the dorsal fin origin and caudal peduncle), girth (g), precaudal length (pcl), and total length (TL) in millimeters, and weight (kg) were recorded. Weights were not taken in all cases because scales of sufficient capacity were not always available.

The reproductive tracts of individuals of both sexes were examined to determine maturation. Male sharks were categorized as either juvenile or adult (Holden and Raitt 1974). Five indices were used to determine maturity in male sharks. These indices included (i) measuring and plotting the inner clasper length against total length. As the male sevengill approaches maturity, the claspers lengthen and stiffen. An increase in the clasper length versus total length indicates maturity (Chen and Mizue 1973), (ii) with the onset of maturity development of the clasper sac can be observed along the claspers of sevengills, (iii) the presence of a straight versus coiled wolffian duct. With the onset of maturation the wolffian ducts enlarge and coil (Cailliet et al. 1981), (iv) sperm smears were taken by applying pressure along the posterior end of the wolffian duct. Finally, (v) a field test for the presence of sperm was made by cross-sectioning the kidney and examining the wolffian duct, a test which Pratt (1979) used to indicate maturation in the blue shark, *Prionace glauca*. Length-weight relationships were plotted and combined with the information above to indicate approximate size at maturity.

Sexual maturity of female sharks could only be determined by internal examination. Females were categorized as juvenile, adolescent, or adult. The developmental stage was determined by the condition of the ovaries (Holden and Raitt 1974). Females were considered adult when the ovaries contained large yellow eggs 22 to 75 mm in diameter. Pregnant females were those with eggs or embryos in the oviduct. The number and size of eggs (>18 mm in diameter) or embryos per female were recorded to determine fecundity and size at parturition. A graph depicting the length-weight relationship of females was plotted and combined with the information above to indicate approximate size at maturity.

During the course of this investigation several sevengills were observed to bear scar and tooth marks that had been inflicted by other sharks. Total length, sex, and location of those wounds were noted.

Stomachs were dissected and the contents identified. Food items not identified in the field were preserved in 10% formalin and returned to the laboratory. Empty stomachs or those containing only bait (squid or mackerel) were noted and discarded. Food items other than bait were identified to the lowest possible taxon, and an index of relative importance for ranking prey items (Pinkas et al. 1971) was calculated.

Vertebral sections were collected for use in age determination. Vertebrae were removed from an area just posterior to the head region. Ageing techniques currently in use for elasmobranch studies at Moss Landing Marine Laboratories (Cailliet et al. 1981, 1983) were tested. These techniques included the use of silver nitrate impregnation and ultra-violet light, x-ray spectrometry, and histology. Since the centra in *Notorynchus,* as with some hexanchids, can only be recognized by the presence of a transverse septum of fibro-cartilage (Ridewood 1921, Maisy and Wolfram 1984), vertebrae were cross-sectioned and examined for calcified rings.

During this study I observed a distinct difference in background coloration of the dorsal region of sevengills from different geographic regions. Observations were made throughout the study to document the extent of this coloration and to describe these color patterns.

Sevengill sharks were examined for visible ectoparasites. Parasite samples were collected and preserved in 10% formalin for later identification.

Some sharks were tagged in order to obtain information on movement patterns and growth.

RESULTS AND DISCUSSION

Information on 128 sevengill sharks was gathered from November 1981 through June 1983. Of this total, 96 sevengills were taken in Humboldt (12) and San Francisco (84) bays. Additionally, information on 32 sevengills was obtained from several California institutions.

Seasonality

The occurrence of sevengill sharks in Humboldt and San Francisco bays during the spring and summer appears to suggest a seasonality. Some sevengills are caught year-round, however, the numbers caught in Humboldt and San Francisco bays was higher during the spring through early fall months. This observation is further supported by commercial fishermen in Humboldt and San Francisco bays who concentrate their efforts on sevengills during the spring and summer months due to their abundance at this time (K. Bates, Eureka and D. Kittredge, San Francisco, California, commercial fishermen, pers. comm.). Only a relatively small number of elasmobranchs, predominately the spiny dogfish, *Squalus acanthias,* were caught in San Francisco Bay during the winter period despite the use of several types of fishing gear. De Wit (1975) also reported the predominance of spiny dogfish during the winter months in San Francisco Bay.

The seasonal occurrence of sevengills follows the appearance of other elasmobranch species in these bays suggesting a possible migration sequence. According to commercial shark fishermen in both Humboldt and San Francisco bays sevengills become prominent in the overall catch during the spring after several other elasmobranch species have appeared. The sevengill catch also decreases prior to a reduction in the catch of other elasmobranchs during the late summer, early fall periods. Future studies on the sevengill shark using tag and recapture or telemetry methods may reveal a complex movement pattern into and outside of these bays.

Maturity

My results indicate that all male sevengills over 150 cm TL are mature. Size at sexual maturity was determined by analysis of 71 specimens that ranged from 44 to 242 cm TL. Eighteen of 71 specimens were mature. The clasper length increased abruptly at approximately 150 cm TL (Figure 2) and with development of the clasper sac mechanism indicated the onset of sexual maturity.

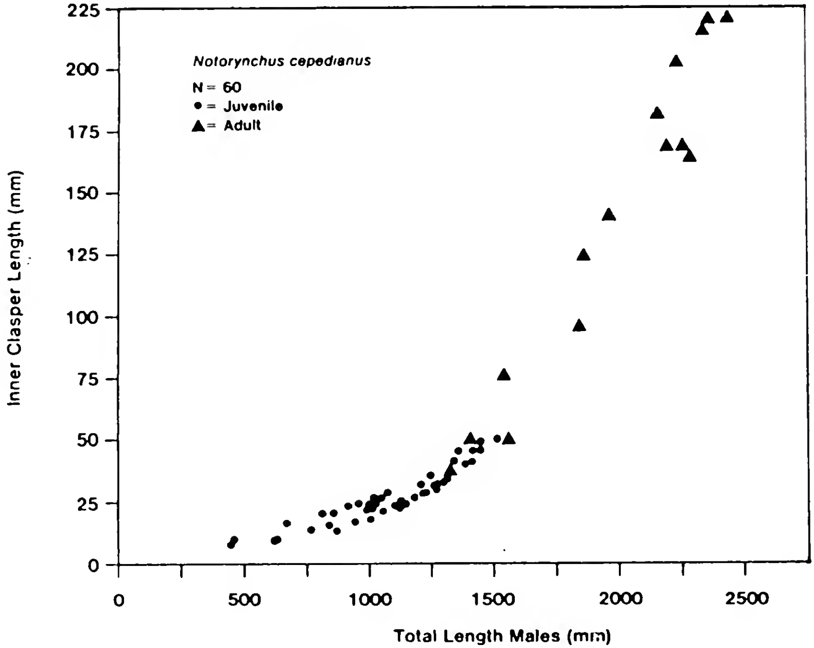

FIGURE 2. The inner clasper length (mm) versus total length (mm) for 60 sevengill sharks.

Coiling of the wolffian duct and expulsion of sperm through the genital papilla are conclusive indicators of maturity. Examination for the presence of sperm were negative except in those male sevengills with a fully coiled and enlarged wolffian duct. Sperm smears disclosed that sharks were fully mature when sperm could be expelled. Sperm smears collected at the genital papilla proved to be an easier method for determining maturity than taking a cross-section through the wolffian duct. The wolffian ducts of mature sevengills collected at various times of the year all contained viable sperm.

Weights to the nearest 0.5 kg were obtained for 22 males ranging between 45 cm (0.5 kg) and 242 cm TL (79.5 kg). The length-weight curve for male sevengills began to more rapidly increase in weight at 150 cm TL (Figure 3). Male sevengills of 153 cm TL and weighing 13.5 kg were fully mature.

Examination of the reproductive tract for 57 female sevengills, ranging between 78 cm and 291 cm TL, revealed that 48 were juveniles, three were maturing (adolescents), and six were adults. Those in the juvenile stage had ovaries that were small and contained no eggs or follicles. Juvenile females were recorded up to 186.5 cm TL. Two of the three adolescent females (219 and 221 cm TL) examined contained approximately 100 eggs per ovary, ranging from 0.5 to 18 mm in diameter. The third was smaller (164 cm TL) and contained only 75 eggs per ovary, ranging from 0.5 to 10 mm in diameter.

Fecundity varied from 82 to 95 large (> 22 mm in diameter) yellow vascularized eggs per female. The number of eggs per ovary in mature sevengill sharks ranged from 39 to 55, with numerous smaller eggs (< 18 mm in diameter) present. The left ovary contained 2 to 16 more eggs.

A consistently unimodal distribution of egg size in individual specimens suggests that only one group of eggs develop at a time. Evidence for this came from a female examined during May that contained 82 near-term embryos but no large eggs in the ovaries. This is plausible since female sevengills carry between 82 and 95 eggs or embryos at a time and the size at parturition is quite large (approximately 45 cm TL). Egg size in adult females is approximately 75 mm in diameter prior to fertilization. Female sevengills with large eggs (55 to 75 mm diameter) present in their ovaries, but lacking embryos were caught during May and early June. These specimens also bore severe mating scars. Eggs from another female sevengill examined during June were small (22 to 41 mm diameter) and based on egg size, parturition had already occurred in this specimen. Therefore, it appears the next generation does not initiate development until after parturition.

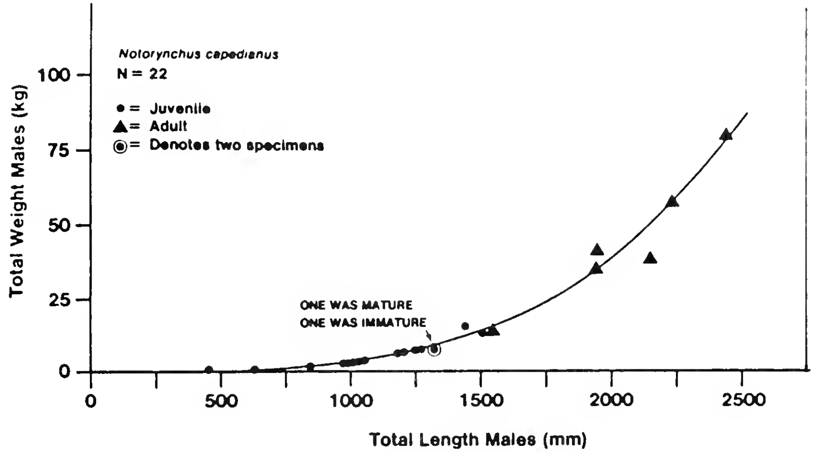

FIGURE 3. Total length (mm) versus weight (kg) for 22 male sevengill sharks.

Developmental stages and their proposed timing for the sevengill shark is presented in Figure 4. Sevengills enter bays during the spring and females with developing eggs or embryos have been observed during this time. The length of time for large yellow eggs (approximately 75 mm in diameter) to develop is uncertain. However, assuming Herald and Ripley's (1951) speculation that sevengills enter San Francisco Bay for breeding is correct, then the time from parturition to fertilization may be from 6 to 12 months. Additionally, based on Holden's (1974) calculations for *Hexanchus griseus,* the time from fertilization to parturition (gestation) would extend another year. Therefore, after first parturition adult female sevengills would give birth every 18 to 24 months.

Female sevengills mature at about 250 cm TL and weigh in excess of 91 kg (Figure 5). A sharp increase in the weight of females occurred after 200 cm TL as they approach adulthood. The smallest adult female I examined (268 cm TL, 127.3 kg) was slightly larger than a 264 cm TL specimen reported by Herald (1968). The largest female sevengill recorded was 291 cm TL and weighed in excess of 182 kg. The largest previously reported sevengill was a 288 cm TL specimen caught in New Zealand (Phillips 1935).

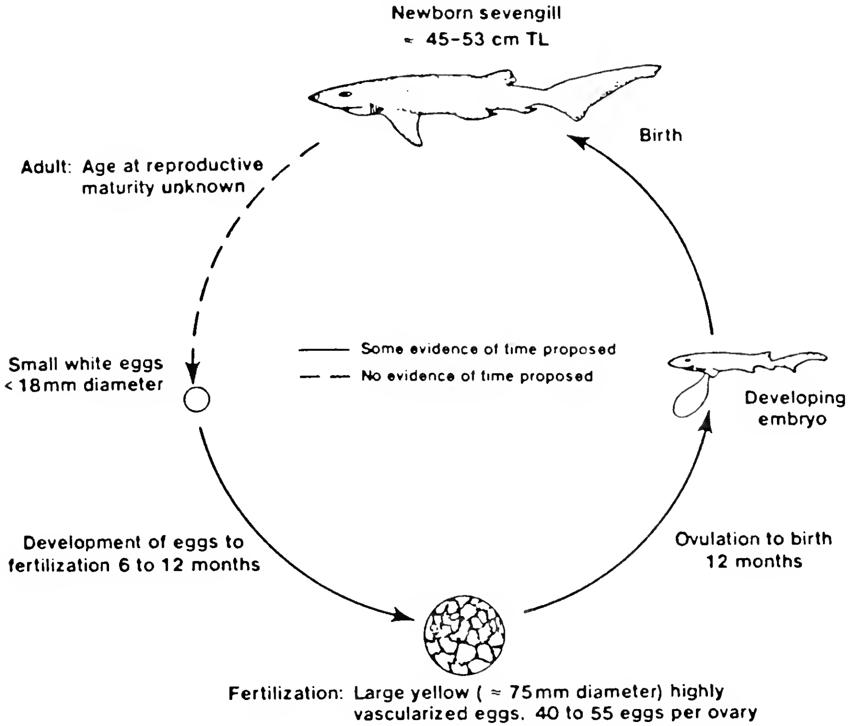

FIGURE 4. A schematic diagram of the developmental stages and their proposed timing in the sevengill shark. Length of lines are not proportional to times proposed.

Bite Injuries

Two adult and two adolescent female sevengills were scarred. Both adults had three types of wounds that appeared specific to certain areas of the body. Fresh tooth slashes were observed on both of the adults and appeared as parallel straight or curved cuts. They were superficial and confined to the dorsum, anterior to the dorsal fin. Baldridge and Williams (1969) reported similar tooth slashes on the head of a dusky shark, *Carcharinus obscurus,* were from another shark, but they could offer no explanation for these scars. Fresh semi-circular jaw impressions showing continuous tooth marks were observed on both paired fins of one specimen. The other adult female had only a healed semi-circular jaw impression on its left pectoral fin. Single, straight, deep tooth cuts were observed laterally between both paired fins. Adolescent females had tooth slash marks similar to those seen in the adults.

Fresh tooth cuts and semi-circular jaw impressions on gravid females caught in Humboldt Bay and San Francisco Bay during the spring and early summer suggest a possible breeding season. Breeding seasonality has been observed in several shark species (Olsen 1954, Jones and Geen 1977, and Parsons 1983) and it is well known that male sharks often bite their mates during copulation

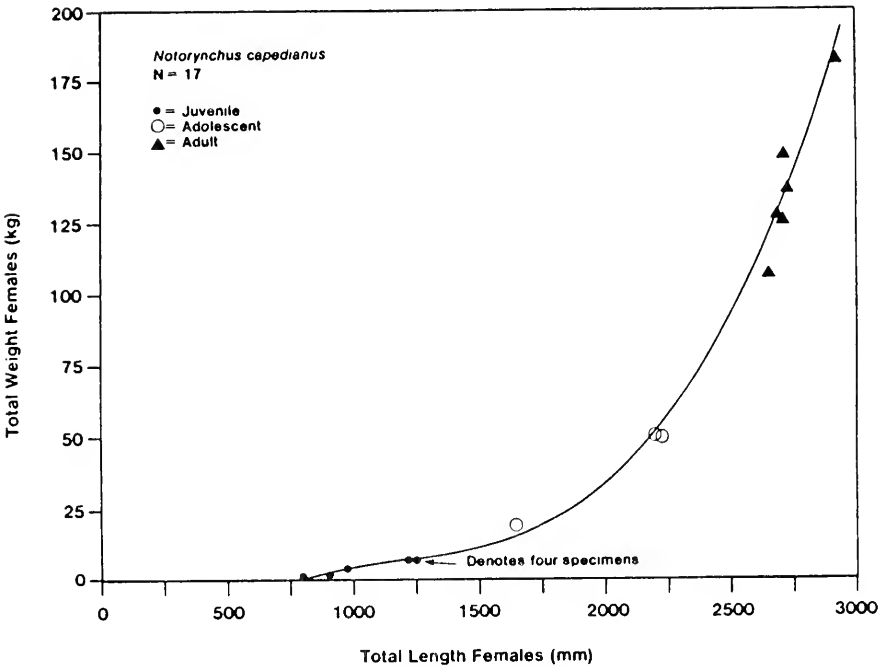

FIGURE 5. Total length (mm) versus weight (kg) for 17 female sevengill sharks.

(Gilbert 1981). Also, adult females that presumably had recently given birth lacked fresh wounds suggesting these cuts are inflicted only when the female is ripe. Healed wounds, appearing as white patches of scar tissue, were observed on these specimens.

Six mature male sevengills were observed to have slashes and tooth cuts laterally between the dorsal and tail fins. Occasionally, slashes were observed more anteriorly toward the head region. Parts of the dorsal and caudal fins were occasionally missing. No marks of any kind were observed on juveniles of either sex.

Food Habits

Sevengill sharks appear to be top predators in the bay ecosystem. Food items in sevengill stomachs included representatives of six groups: cartilaginous fishes, bony fishes, marine mammals, molluscs, lampreys and decapod crustaceans. The cartilaginous and bony fishes were the two major prey groups eaten by sevengills.

Five species of elasmobranchs were found in sevengill shark stomachs, four of which were important prey items (Figure 6). The brown smoothhound, *Mustelus henlei,* represented the single most important prey species in the sevengill's diet; bat rays, *Myliobatis californica*, also ranked high. Bony fishes as a group were important in the sevengill's diet, but most were partially digested and could not be identified to species. Larger sevengills (>268 cm TL) consumed harbor seals, *Phoca vitulina,* on three separate occasions. According to fishermen (K. Bates and D. Kittredge, pers. comm.) marine mammal remains in sevengill guts are not unusual. It is unknown whether the marine mammals were dead or alive before being ingested. Other prey items reported found in sevengills include the big skate, *Raja binoculata,* dolphin, human remains, jack smelt, *Atherinopsis californiensis,* and rats (K. Bates, pers. comm. and Compagno 1984).

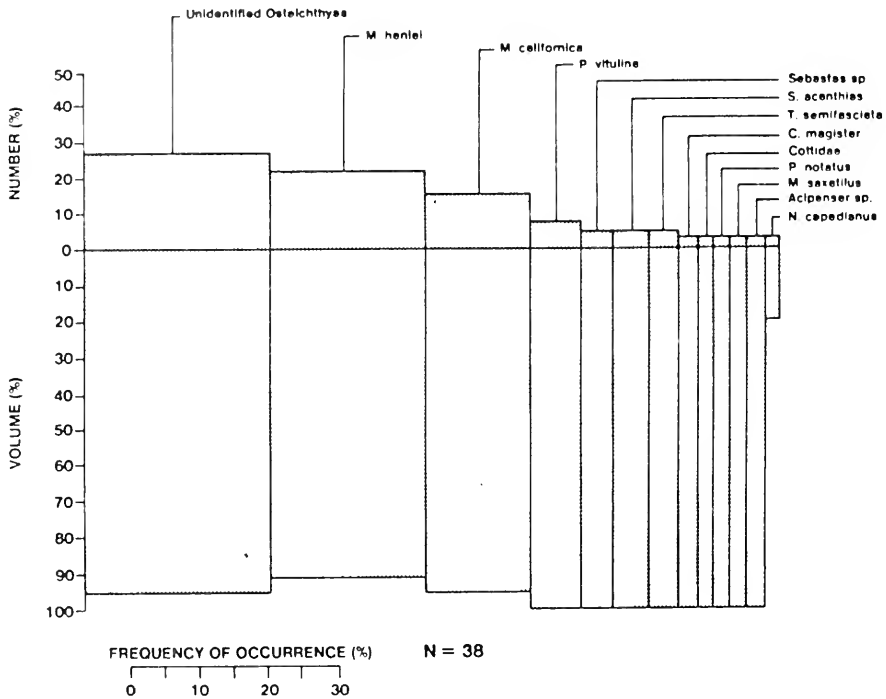

FIGURE 6. Index of relative importance for the prey items found in the stomachs of 38 sevengill sharks.

Ageing

None of the three methods tested to age sevengill sharks by using their vertebrae proved successful. The use of vertebral rings to age sevengills was not possible due to a lack of calcification in the vertebrae (Bass et al. 1975, Ridewood 1921). The use of other hard parts for ageing hexanchids seems unlikely since elasmobranchs continually replace teeth and scales tend to be variable (Applegate 1967). Unless new techniques are developed, the ageing of the sevengill shark may be dependent on tag and recapture studies.

Color

The dorsal background color of sevengill sharks collected from Humboldt Bay typically ranged from a pale silvery gray to reddish brown. These colors were consistent and were observed in both sexes. Although no observations were made on small specimens (210 cm TL), coloration did not appear to be related to size. Sevengills collected in San Francisco Bay had a dorsal background color ranging from olive brown to muddy gray. These colors also did not appear to be related to size or sex and were consistent for all specimens examined from San Francisco Bay with the exception of one piebald colored sevengill caught off Hunter's Point (Ebert 1985).

Parasites

Three species of parasites were observed on sevengills. The copepod, *Pandarus bicolor* (Pandaridae), was observed on 56 specimens. *Pandarus bicolor* was recorded on both the paired and unpaired fins with some being observed on the dorsal and ventral body surfaces. Russo (1975) also noted the abundance of *P. bicolor* on sevengills, particularly on the trailing edges of the fins. The leech, *Branchellion lobata* (Piscolidae), was observed twice. Once in the oral cavity of a 164 cm female and another on the pelvic fins near the cloacal opening of a 268 cm female. *Branchellion lobata,* was reported by Russo (1975) on the claspers, fins, and buccal cavity of sevengill sharks. A parasite not mentioned by Russo (1975), the isopod *Lironeca vulgaris* (Cymothoidae), was observed in the gills of three sevengills. This is a common gill parasite found on many species of marine teleosts (Morris et al. 1980). The occurrence of *L. vulgaris* may be difficult to measure as they were observed to quickly abandon their host upon capture.

CONCLUSION

Sevengill sharks are a seasonally abundant, poorly understood, apex predator in several northern California bay ecosystems. The seasonal occurrence of sevengills in these bays appears to correspond with their reproductive cycle, since adult females caught during the spring and summer had large eggs or embryos and mating scars. The importance of the sevengill shark to the bay environment and their activity outside of bays is for the most part unknown and more information is needed to confirm movement patterns within and outside of bays.

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RICE AVAILABLE TO WATERFOWL IN HARVESTED FIELDS IN THE SACRAMENTO VALLEY, CALIFORNIA [1]

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Rice fields in the Sacramento Valley, California were sampled in 1985 and 1986 to determine the weight of rice seed remaining in the fields immediately after harvest and again after the fields were burned. No significant differences were found between years ($P > 0.05$). The pooled mean was 388 kg/ha in harvested fields and 276 kg/ha in burned fields. These values are less than estimates previously available. The values for harvested fields both years were no different ($P > 0.05$) than values obtained by the U.S. Department of Agriculture (USDA). Surveys of rice fields in December both years showed that most fields were left either harvested (26–32%) or burned (37–40%) through the winter. Fields flooded for duck hunting made up ≤15% of the total. The proportion of fields plowed by December increased from 14% in 1985 to 22% in 1986. Sixty-three percent of all fields that had been flooded for hunting were drained within two weeks after the end of the hunting season. Harvest yield, field size, levee type (contour, lasered), straw status (spread, windrowed), harvest date, and rice variety did not affect the quantity of seeds remaining after harvest ($P > 0.05$). One harvester model, the Hardy Harvester, left more rice in fields than did others we tested ($P < 0.001$). Specific management programs are recommended to mitigate annual variation in rice seed availability to waterfowl caused by differences in total hectares grown (15% less in 1986) and in the proportion of fields burned and plowed.

INTRODUCTION

Rice farms have displaced much of the original marshland in the Sacramento Valley, California (Gilmer et al. 1982). Rice seed left in fields after harvest sustains many waterfowl species during winter, including Northern Pintails, *Anas acuta,* Mallards, *A. platyrhynchos,* American Wigeon, *A. americana,* and geese, *Branta* and *Anser* spp. (Miller 1987; California Dept. Fish and Game, Sacramento and Sacramento National Wildlife Refuge, Willows, California, unpubl. data). Accurate estimates of rice availability are needed to determine the potential number of waterfowl that can be fed per hectare of harvested rice. However, no published information was available for California on the quantity of rice in harvested fields before and after burning.

The USDA's Rice Objective Yield Survey (ROYS) (U.S. Dept. Agric. 1985) includes unpublished measures of loss after harvest. However, the program

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wasn't operational in California in 1985, and data are not collected in burned fields. Other unpublished studies reported losses of 79–820 kg/ha after harvest in California, but the studies sampled few fields, small sample plots (≤ 0.1 m ^{2}), and only one plot/field (R.G. Curley and J. R. Goss, unpubl. rept., Dept. Agric. Eng., Univ. Calif., Davis, Feb 1964, 3pp - 1955 data; M. Dennis, U.S. Soil Conserv. Serv., Willows, Calif., Oct 1978), or supporting data were not provided (Sacramento Valley Waterfowl Habitat Management Committee, no date, p. 201). These California estimates are not adequate for waterfowl management.

In the southeastern United States (Louisiana, Texas, Arkansas), investigators found 140–223 kg/ha of rice in harvested fields (Harmon et al. 1960; Hobaugh 1984; K. J. Reinecke, U.S. Fish and Wildl. Serv., pers. comm.). However, these estimates are not applicable to California because the average yield of rice in California is up to 50% greater (U.S. Dept. Agric. 1987), specific rice varieties and seed sizes differ (Willson 1979, U.S. Dept. of Agric. 1987:A–33), and harvested fields are burned in California but not in the south (Huey 1971, K. J. Reinecke, U.S. Fish and Wildlife Service, pers. comm.).

At present, a method is not available to monitor annual trends in harvest loss. Modern harvesters may improve harvest efficiency and leave fewer seeds for waterfowl (Gilmer et al. 1982). Also, rice land is less extensive during droughts and federal farm programs. Knowledge of carrying capacity of harvested rice may enable waterfowl managers to anticipate food shortages and take compensatory action. Decisions on food production on National Wildlife Refuges, State Wildlife Areas, and private hunting clubs would be facilitated with better knowledge of the amount of food available on farm lands.

Our objectives were to: (i) estimate the mean weight of rice remaining in harvested fields in the Sacramento Valley before and after burning (and plowing if time allowed), and derive 95% confidence intervals that are within ±20% of these means; (ii) derive optimum sampling designs with various combinations of numbers of fields vs. number of plots/field to achieve objective precision and minimize time and cost; (iii) compare results from harvested, unburned fields with data obtained by the USDA ROYS program to determine if that survey can be used to monitor annual rice availability; (iv) document the status of rice fields at the beginning of the rainy season (harvested, burned, flooded for duck hunting, plowed); and (v) determine the rate at which flooded rice fields are drained after the duck hunting season ends.

METHODS

We conducted field work in the fall of 1985 and 1986 in Colusa, Butte, Sutter, Glenn, Yolo, Yuba, Sacramento, and Placer counties in the Sacramento Valley. These eight counties contributed $>92\%$ of all rice grown in the Central Valley, and $>99\%$ of all rice in the Sacramento Valley (Calif. Agric. Stat. Serv. 1987). A list of >300 rice growers was obtained for the eight counties. We randomly contacted growers, in the order selected, to participate in the study until the required number of fields was identified (100 in 1985); this was achieved with

59 growers. We next obtained a map of each grower's rice fields, assigned a number to each field, and randomly selected study fields irrespective of rice variety and field size. We selected a maximum of two fields/grower, but we allowed up to four in large (>725 ha) corporate farms where more than one farmer grew and harvested the rice.

We initially selected sample fields among counties according to the percent of rice hectarage within each county. However, not all fields were burned, a few were burned before we could obtain a harvested sample, and some burned fields were flooded or plowed before we could obtain a burned sample. Therefore, as time allowed, we sampled additional harvested and burned fields. Ultimately, we obtained samples of long, medium, and short rice varieties from 111 harvested fields and 89 burned fields (Table 1). We only had time to sample four plowed fields. We used aircraft and ground vehicle surveys to check field status (harvested or burned) daily to assist in locating fields quickly.

In 1985, we obtained samples within each field from two sites (plots) before burning, and two additional sites after burning. Each site was located at the intersection of two random coordinates. Sample plots measured 0.3 m by 5.5 m, the latter value the length of a standard harvester header, and were laid out perpendicular to the direction of harvester travel. We used pruning shears to cut straw and standing stubble from within the plots. The straw, containing seed heads, was saved in a labeled sample bag. We vacuumed the area within the sample plot with generator-powered shop vacuums and bagged the sample. We separated rice seeds from straw, other seeds, and dirt with a portable threshing machine and power seed cleaner. Final separation was done by hand before the seeds were dried (70° C) to constant weight. In 11 randomly selected fields, we separated the vacuumed (ground) and straw samples to determine what percentage rice in each contributed to the total.

Analysis of 1985 data showed that desired precision could be attained by sampling more plots/field in fewer fields because variation within fields exceeded that among fields (SD = 45 vs. 17). Therefore, in 1986 we collected data from 15 randomly selected fields at a rate of eight plots/field (Colusa, Butte, Sutter, Glenn, Yuba, and Yolo counties). The total number of sample plots was reduced by about half from that in 1985 (Table 1). We located post-burn sample sites about 3 m away from pre-burn sample sites in the same harvester path. Not all fields were burned, so ultimately we sampled 15 harvested and 11 burned fields. In 1985, we had sampled 10 plots in one field before and after burning. We randomly deleted two of the plots and added this field to those sampled in 1986 to increase sample size for before and after burn comparisons (not for calculating mean weight).

TABLE 1. The Number and Proportion of Sample Fields of Short, Medium, and Long Grain Rice Varieties, and the Proportions of Each Variety Harvested in the Sacramento Valley, 1985–86.

	Variety			
County	*Short grain*	*Medium grain*	*Long grain*	*Total*
Colusa	2 (1)*	24 (4)	3	29 (5)
Butte	2	13 (3)	6	21 (3)
Sutter	2	12 (3)	5	19 (3)
Glenn	3 (1)	13 (1)	2	18 (2)
Yolo	1	7 (1)	1	9 (1)
Yuba	1	5	1 (1)	7 (1)
Sacramento	1	2	1	4
Placer		3	1	4
Total Fields	12 (2)	79 (12)	20 (1)	111 (15)
Sample %	10.8(13.3)	71.2(80.0)	18.0(6.7)	100.0
Statewide %	19.7	66.8	13.5	100.0

* 1986 data in parentheses.

We derived regression equations to predict the weight of rice in harvested fields from data collected in burned fields (the latter are more easily obtained). We obtained the mean weight of burned and unburned samples of 10 groups of 1,000 seeds of each variety (long, medium, short), and derived regression equations for each variety to predict seed weight from the number of seeds.

In December of both years, we visited 888 randomly located 32.4 ha rice fields distributed among counties proportionate to the amount of rice in each county. We recorded field status as: (i) not harvested; (ii) harvested (unburned, undisturbed stubble); (iii) burned (after harvest); (iv) plowed or disked (after burning); or (v) flooded for duck hunting (after burning). The flooded fields were surveyed beginning eight days after the close of the duck hunting season in January 1987 to determine what proportion had been drained and thereby potentially eliminated for use by ducks.

For statistical analysis, we identified fields as the experimental units. Differences in rice before and after burning were analyzed with a paired *t*-test. Differences between years and treatments (burned, unburned) were determined through analysis of variance, with rice averaged over the plots. We assessed the effect of harvest yield, grain size, date sampled, harvester type, field size, levee type (laser leveled, contour), and straw status (windrowed, spread) on the availability of rice through a model-building approach (Draper and Smith 1981). Each model was evaluated by repeated measures (Milliken and Johnson 1984) with treatment types (burned, unburned) as the repeated measure, and plots as subsamples within each repeated measure. We used analysis of variance to test for differences in seed weights among rice varieties within and between treatments (Snedecor and Cochran 1980), and chi-square analysis for differences in field status between years (Siegel 1956).

RESULTS

We sampled harvested fields between 13 September and 9 November, and burned fields between 23 September and 22 November in 1985 (Figure 1). The mean time between harvest and burn dates and respective sample dates (sampling interval) was three days (SE = 0.2) for harvested fields and 3.1 days (SE = 0.3) for burned fields. In 1986, comparable dates were 2–28 October for harvested fields and 13 October to 17 November for burned fields (Figure 1). The sampling interval was 2.5 days (SE = 0.3) for harvested fields and 2.8 days (SE = 0.3) for burned fields.

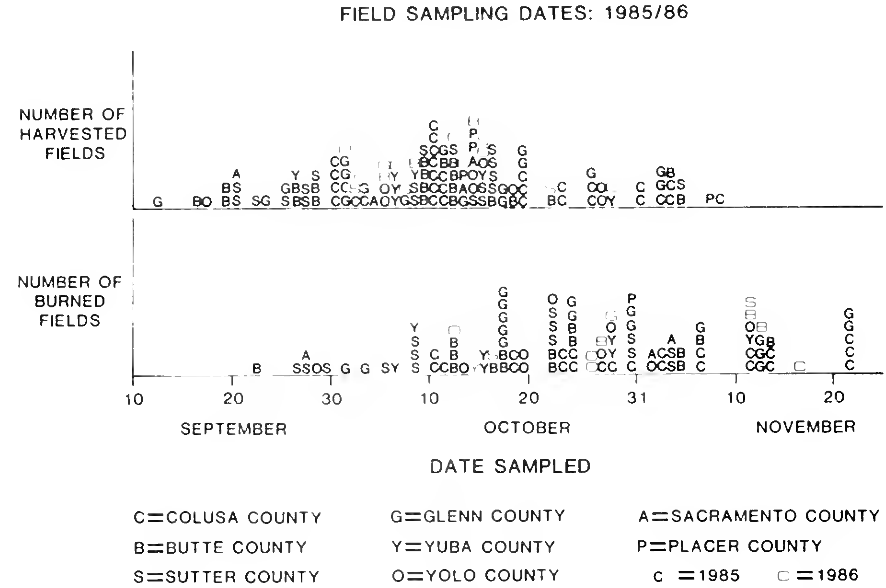

FIGURE 1. Dates on which samples were obtained from harvested and burned fields in the Sacramento Valley during fall in 1985 and 1986.

We detected no significant differences between years in the weight of rice in harvested ($F = 0.01$, $P > 0.05$) or burned fields ($F = 0.01$, $P > 0.05$). The pooled means were 388 kg/ha in harvested fields, and 276 kg/ha in burned fields (Table 2). This difference was significant ($t = 6.78$, $P < 0.001$), and these values were respectively, 4.6% and 3.3% of the 1985–86 average harvest yield in California of 8,420 kg/ha (U.S. Dept. Agric. 1987). The 95% confidence intervals were ±10.6–10.9% of the mean for 1985 and pooled data, and ±25.9–27.8% of the mean for 1986 data (Table 2).

TABLE 2. Annual and Pooled Mean Weights (kg/ha) of Rice in Harvested and Burned Fields in the Sacramento Valley, 1985 and 1986.

Field Status	*Year*	*N*	*Weight*	*S.E.*	*95% CI*
Harvested	1985	111	387	21	346, 427
	1986	15	395	51	285, 504
	Pooled	126	388	20	348, 427
Burned	1985	89	276	15	246, 305
	1986	11	278	32	206, 350
	Pooled	100	276	16	244, 307

In a subsample of 11 harvested fields, nearly 75% of all the rice was found on the ground (254 kg/ha, SE = 37) compared to in the straw (91 kg/ha, SE = 17) ($t = -4.98$, $P < 0.001$). We found only 22 kg/ha of rice in the four plowed fields, but larger samples were needed to obtain definitive data. The mean weights of rice in harvested fields as determined in this study were very similar (identical in 1986) to values obtained by the USDA's ROYS program (375 kg/ha in 1985, N = 66, SE = 51.2; 395 kg/ha in 1986, N = 81, SE = 44.9).

Obtaining pre-burn samples was more difficult than post-burn samples because of abundant straw. Therefore, we derived two predictor equations to estimate the weight of rice in harvested fields from weight in burned fields (kg/ha): (i) WEIGHT PRE-BURN = 186.9 + 0.83WEIGHT POST-BURN ($r^2 = 0.41$), for fields sampled with nonpaired plots; (ii) WEIGHT PRE-BURN = 28.0 + 1.19WEIGHT POST-BURN ($r^2 = 0.57$) for fields sampled with paired plots.

Two-way analysis of variance showed that long grain rice was lighter than medium and short grains in mean weight per 1000 kernels; this was true in harvested (long = 20.68 g, SE = 0.06; medium = 22.80 g, SE = 0.03; short = 22.43 g, SE = 0.05; $F = 552$, $P < 0.001$) and burned fields (long = 21.30 g, SE = 0.05; medium = 23.04 g, SE = 0.04; short = 23.23 g, SE = 0.08; $F = 331$, $P < 0.001$). Within varieties, the mean weight per 1000 kernels from burned fields exceeded that from unburned fields ($F = 107$, $P < 0.001$). This may have been an artifact of seed selection, in that some unburned seeds were not fully mature, so not completely representative. In the burned fields, immature seeds were consumed by fire, or seed coats were burned away, so fewer immature seeds were available for selection.

Seed dry weight (g) may be estimated from seed numbers if the grain variety is known: (i) Harvested Fields: LONG GRAIN = 0.003 + 0.021X; MEDIUM GRAIN = −0.009 + 0.023X; SHORT GRAIN = −0.009 + 0.022X; (ii) Burned Fields: LONG GRAIN = −0.029 + 0.021X; MEDIUM GRAIN = 0.012 + 0.023X; SHORT GRAIN = −0.032 + 0.023X, where X = number of seeds, and in all equations, $r^2 = 0.999$.

Analysis of variance showed that the weight of rice in harvested and burned fields was not explained by harvest yield, grain size, field size, straw status, levee type, or date sampled ($P > 0.05$). Hardy Harvesters left more rice in fields after harvest, both as total rice and total rice as a ratio with yield, than did the others tested ($F = 14.3$, $P < 0.01$; $F = 10.47$, $P < 0.01$, respectively). There were no significant differences among the others ($P > 0.05$). The only factor that explained the weight of rice in burned fields was the weight of rice before burning ($r^2 = 0.50$, $P < 0.01$).

The survey of field status in early December showed that no rice fields remained unharvested either year (Table 3). The largest proportion of the fields remained burned and there was no difference between years ($X^2 = 0.77$, 1 df, $P > 0.05$). The proportion of plowed fields increased markedly between 1985 and 1986 ($X^2 = 16.3$, 1 df, $P < 0.05$), and this increase occurred in all eight surveyed counties. Sutter County was most impacted by plowing (24% in 1985, 39% in 1986). In other counties, plowing varied from 0 to 30%, with Glenn (16 and 25%), Yolo (15 and 30%), Sacramento (25 and 28%), and Yuba (5 and 22%) most affected. Nearly 60% of Yuba County's rice was flooded, but the proportion of flooded fields varied from none in Sacramento County to 12–19% in Colusa and Butte Counties. Of fields flooded for duck hunting in 1986, 63% were drained within two weeks after the end of the duck hunting season (Table 3). Colusa and Glenn Counties retained the fewest flooded fields after the season with ≥85% drained, whereas in Yuba County, only 34% were drained.

Drainage rates in the other counties ranged from 62–71%. The total hectares of rice grown and harvested in California declined 15% from 1985 to 1986 (Table 3).

TABLE 3. Status of Rice Fields in the Sacramento Valley, California in December (Percentages of All Sampled Plots; N = 888), Percentages of Flooded Fields Drained Within 10 Days After the Hunting Season in January 1987 (N = 128), and total hectares harvested in the Sacramento Valley 1985–86.

	December				*January*	*Total hectares*
	Harvested	*Burned*	*Plowed*	*Flooded*	*Drained*	*harvested*
1985	32	40	14	14	—	161,880
1986	26	37	22	15	63	137,600

DISCUSSION

The amount of rice we found in fields after harvest is markedly less than previous estimates for California. However, the absence of differences in mean weight of rice/ha between years suggests that on a per hectare basis, the mean amount of rice is stable over the short term. The greatest effect annually on the amount of rice available to waterfowl depends on total hectares harvested, burned, and plowed. For example, we applied the status percentages to the hectares harvested (Table 3), and used the kg/ha values for harvested, burned (used also for flooded), and plowed fields to derive a total of 44.5 million kg of rice in fields in 1985, and 34.0 million kg in 1986. To illustrate the potential impact of these annual differences on waterfowl populations, we arbitrarily assigned 60 g as a hypothetical daily intake of rice for waterfowl in the Sacramento Valley for October through February. We used this to determine a hypothetical number of birds fed: 44.5 million kg of rice/0.06 kg consumed per day/150 days (Oct–Feb) = 4.94 million ducks in 1985 and, with similar calculations, 3.78 million ducks in 1986. This theoretical 24% decline in carrying capacity resulted primarily from the reduced hectares and increased plowing in 1986.

Not enough data are available from previous years in California to determine if there has been a downward trend in rice available to waterfowl. However, because our results closely matched those of the USDA ROYS program, their data may be used to monitor future trends. These data may be obtained from the Agricultural Statistics Board, South Agriculture Bldg., Room 4133, Washington, D.C. 20250, or the Calif. Dept. of Food and Agriculture, Agricultural Statistics Service, 1220 N Street, Room 243, Sacramento, CA 95814.

The quantity of rice left in fields after harvest in California was 1.2 to 2.8 times more than in harvested fields in the southeastern United States (Harmon et al. 1960; Hobaugh 1984; K. J. Reinecke, U.S. Fish and Wildl. Serv, pers comm.). This disparity resulted from the markedly greater yields (1985–86 means, all varieties) obtained in California (8,420 kg/ha) compared with the southeast (5,895 kg/ha in Arkansas, 5,010 in Louisiana, 6,035 in Mississippi, and 6,590 in Texas) (U.S. Dept. Agric. 1987). In corn, losses increase with increasing yields because harvester efficiency cannot keep up with the increasing yields (Warner et al. 1985). This probably occurs as well with major increases in rice yield. A new, more productive, long grain variety (Lemonte) has been developed for use in the southeast that may eliminate the disparity in yields between the two regions (Anonymous 1985).

There was 30% less rice in fields after burning. Some of this loss might be attributable to feeding by waterfowl and other birds. However, we were alert to evidence of waterfowl feeding in the vicinity of sample plots and avoided those locations. This, together with the short elapsed time between burning and sampling, leads us to conclude that the loss of rice resulted primarily from destruction during the burn. Most of this loss probably was in the portion of the rice still in the straw, because 26% of the rice in harvested fields was in the straw.

The effect of burning on availability of rice resources for waterfowl feeding is not known because we do not know what percentage of rice in a harvested field is consumed by waterfowl. In a burned field, the seed is visible and, based on subjective evaluation of fields after waterfowl have fed in them, all seed may be available for consumption. Before the burn, the large quantity of straw obscures much of the rice, and an unknown portion of the seeds remain uneaten. In other studies, waterfowl have been found to consume 75–80% of grain present in harvested barley (Clark and Greenwood 1987) and corn (Baldassarre and Bolen 1984). Research is needed to determine depletion rates and feeding efficiency in rice fields.

Because of the dry autumns, all fields in the Sacramento Valley were harvested each year. September and October 1986 were particularly dry, and this encouraged growers to plow more of their harvested/burned fields than in 1985. That nearly one fourth of all fields were plowed by December 1986 is cause for concern. In certain counties, especially Sutter, Glenn, Yolo, and Sacramento, the problem is severe. Our limited sampling in plowed fields suggests that little rice remains easily available to feeding waterfowl. We observed large flocks of ducks and geese feeding in plowed fields, but only after the fields were flooded. Development of a sampling scheme to determine available rice in such fields will be complicated by the absence of information on the depth to which feeding birds will probe in search of seeds.

The problem of early draining of flooded rice fields after the hunting season ends is acute in all counties sampled except Yuba. Drainage of this habitat eliminates roosting space and productive feeding areas (Gilmer et al. 1982). Invertebrates, especially midge larvae, are common in flooded rice fields post-season (Miller 1987), but midges die within 10 days of drainage (Darby 1962). Also, most of these flooded fields have been hunted throughout the season. This probably prevents complete use of all rice, and perhaps other seeds, by waterfowl. If the fields were to remain flooded post-season, these foods could be used.

Long grain rice was lighter in weight than were medium and short grains. Assuming all varieties contain similar metabolizable energy levels, feeding waterfowl would have to consume about 10% more seeds to obtain the same weight when feeding in fields of long grain compared to the other varieties. If market conditions in California change to cause an increase in the hectares of long grain rice (now about 6%) (Calif. Agric. Stat. Serv. 1986) at the expense of medium and short grains, feeding waterfowl will not benefit.

Meteorological conditions affect the efficiency of harvest machinery (Willson 1979, Miller et al. 1985). The most active period of rice harvest in this study was October. Weather conditions then could affect rice availability later in winter. For example, above normal rainfall in October could decrease the rate at which fields are harvested and extend the period before harvested fields are burned and subsequently flooded or plowed. At the same time, harvest efficiency is reduced in wet conditions (Miller et al. 1985), so the amount of rice available to waterfowl ultimately would be increased.

There are differences among harvesting machines in harvest efficiency (Miller et al. 1985), and of those available for testing in this study, Hardy Harvesters left more rice on the ground. This is important because Hardy's made up about 20% of the harvesters on our study fields. Thus, any changes in the proportion of Hardy's used may affect the amount of rice available for feeding waterfowl.

In determining rice present after harvest, we did not differentiate between old and new Hardy Harvesters, and we found no significant differences between old and new models of the others. Large sampling variation, resulting from differences in rice variety, humidity and other weather parameters, harvest yield, operator skill, harvester speed settings, and the use of several different harvesters in a given field, masked any differences (Willson 1979, Miller et al. 1985). As a result, we couldn't conclude whether or not rice harvest is becoming more efficient, causing a concomitant reduction in rice available to waterfowl.

Increased harvest efficiency does not necessarily result in increased farm income for rice growers (Miller et al. 1985) because income is based on the quality as well as quantity of rice delivered to buyers. Quality is measured by the amount of whole, unbroken, and uncracked milled seed (head rice). For example, for the M201 rice variety, (a medium grain that was the most commonly used variety during our study), Miller et al. (1985) found that total yield increased as the cylinder speed of the harvester increased. However, this procedure decreased the proportion of head rice. Thus, total income actually declined with increased harvest beyond a threshold level. Virtually all growers in our sample fields set harvester cylinder speed to maximize harvest. If rice growers harvested for income rather than for total yield, more rice could be available for waterfowl.

When investigators plan rice field sampling schemes, consideration must be given to the time and money available as well as the sampling precision required. In general, sampling fewer fields at a higher rate will save time and money. We drove >16,000 miles and recorded 25 hours of aircraft time with a crew of four to sample the 111 harvested and 89 burned fields in 1985. In 1986, we drove 4,500 miles with a crew of two to obtain our samples, and the sampling interval was reduced. Sampling 15 fields with eight plots/field theoretically should have yielded a confidence interval ±20% of the mean. However, we actually achieved only ±27% suggesting that variation within or among fields was greater in 1986 than anticipated with 1985 data. However, acceptable precision could have been attained by adding fields or plots/field. To plan an efficient sampling regime, relative to precision requirements and specific questions being asked, the number of fields and plots must be assigned based on known variation among (S_a^2) and within (S_w^2) fields. The general sampling formula for harvested fields, to achieve a confidence interval that is ±20% of the mean ($\bar{X}$), is: $F = 606/\bar{X}^2 (S_a{}^2 + S_w{}^2/N)$, where F = number of fields required, $\bar{X}$ = 364 kg/ha, $S_a{}^2$ = 1733, $S_w{}^2$ = 12,362, and N = number of plots specified; for burned fields, $\bar{X}$ = 242 kg/ha, $S_a{}^2$ = 0, and $S_w{}^2$ = 7339.

MANAGEMENT IMPLICATIONS

The amount of rice in harvested fields in the Sacramento Valley is less than previously estimated, and the amount of rice is annually variable and unpredictable. This unpredictability results from annual changes in hectares of rice grown in the Valley; the amount of rice lands burned, plowed, and flooded; and the rapid dewatering of flooded fields at the end of duck season. These facts present waterfowl managers with the need to develop management programs to compensate for this variation in the rice food supply.

Restoration and development of marshes in the Sacramento Valley (State, Federal, private) would help to mitigate this variability by providing a more predictable food supply, and providing a hedge against future improvements in harvester efficiency. The quantity of foods in well managed wetlands exceeds that in harvested rice fields (Fredrickson and Taylor 1982). Rice fields in the Sacramento Valley are extensions of the managed wetlands. Much of the rice is grown on soils not suited for other crops (Willson 1979); therefore, restoration, where practical, should be promoted on lands that support crops of no value to waterfowl. Food production could be increased, in some instances, on existing wetlands through more intensive management.

Incentives need to be developed to encourage rice growers to leave their harvested fields unplowed in the fall, while at the same time entering into hunting programs to increase the amount of fall flooding of harvested fields in certain areas. In addition, growers could be encouraged to manage set-aside lands as marshes. Duck club owners and operators should be encouraged to retain water on rice fields as long after the end of hunting season as practical. Research is needed to determine the relationship between post-season flooding and harvest yield the following fall. Growers should be encouraged to use harvesting techniques that maximize income, not necessarily total yield, thereby increasing the amount of rice for waterfowl. Mechanisms for accomplishing these goals by working with rice growers already exist through extension efforts of the U.S. Fish and Wildlife Service, University of California, Soil Conservation Service, California Department of Fish and Game, and the California Waterfowl Association (Heitmeyer 1988).

Waterfowl managers should monitor annual trends in harvest losses with data from the USDA ROYS program. Managers need also to keep up with the latest developments in rice varieties and harvesters being used by growers. New varieties tend to be more early maturing; this allows harvest, burning, and plowing to be completed before the fall rains begin, thereby reducing waterfowl food.

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NOTES

PACIFICOGRAMMA STEPANENKOI KHARIN, 1983 (FAMILY GRAMMATIDAE), A JUNIOR SYNONYM OF *PRONOTOGRAMMUS MULTIFASCIATUS* GILL, 1863 (FAMILY SERRANIDAE)

Kharin (1983) described a new genus and species of grammatid fish, *Pacificogramma stepanenkoi,* from Uncle Sam Bank, Baja California Sur, Mexico. We refer the type and only known specimen of this species to the anthiine serranid species *Pronotogrammus multifasciatus* Gill 1863 (threadfin bass). This is the third new name (not in combination) proposed for this species since the original description. Previous synonyms are *Anthias gordensis* Wade, 1946 (or *Holanthias gordensis*; Hubbs et al., 1979: 21) and *Holanthias sechurae* Barton, 1947. Fitch (1982) gave a redescription and synonymy of the species including distributional notes, citing its range as off Portuguese Bend, California, to northern Peru in 40–205 m.

Kharin (1983) placed his new genus in family Grammidae (= Grammatidae), which he did not define. However, his inclusion of *Pseudochromichthys riukiuanus* Schmidt in the discussion indicates that he was using the previous, expanded definition of the family (Lindberg 1971, Nelson 1984). Johnson (1984) restricted the Grammatidae to the Caribbean region *Gramma* and *Lipogramma.* Kharin's discussion of the characters supposedly distinguishing the new genus within Grammatidae is irrelevant, since the generic type is an anthiine serranid, not a grammatid. The characters by which *Pacificogramma* is said to differ from its supposed relatives are exactly those characteristic of *Pronotogrammus multifasciatus.* These are: dorsal spines 10, arched and interrupted lateral line, incised caudal fin, dorsal soft rays 15, gill rakers 13, branchiostegal rays 7, spines on preopercle and maxilla scaled. Kharin's figure of the holotype of *Pacificogramma stepanenkoi* is an adequate rendition of *Pronotogrammus multifasciatus,* and agrees with the numerous specimens that we have examined deposited at the California Academy of Sciences, the Los Angeles County Museum of Natural History, and the Scripps Institution of Oceanography.

The basis for Kharin's misidentification seems to be not only a lack of knowledge of the pertinent literature, but lack of familiarity with the eastern tropical Pacific ichthyofauna. The finding of a putative grammatid, although members of the grammatid-pseudochromid-plesiopid complex are limited to the tropical Atlantic and Indo-West Pacific, should have indicated that further research was necessary. Inexplicably, Kharin reported other specimens of the threadfin bass (as *Holanthias gordensis*) from the type locality of *Pacificogramma stepanenkoi.* Hobson (1975) recorded the first California specimen of the threadfin bass from Santa Catalina Island, and Jones et al. (1985) added two more records. Since then we have located six additional California and one Mexican specimen, bringing the total to ten (Table 1). On this basis we suggest that the threadfin bass should be considered a rare California species, after the criteria of Miller and Lea (1972), rather than an occasional stray.

TABLE 1. Southern California Bight Records of *Pronotogrammus multifasciatus*.

Catalog No.	*Locality*	*Depth m*	*Date*
SIO 74-22	Santa Catalina Island [a]	40	Feb 1974
SIO 79-61	Off Oceanside [b]	66–73	19 Feb 1979
CBB 81.22.2	Off Pt. Fermin [b]	80	18 Jan 1981
SIO 84-6	Off La Jolla	73	1 Mar 1984
SIO 84-35	Off Pt. La Jolla	68	10 Apr 1984
CAS 56964	Off Pt. La Jolla	68	10 Apr 1984
CAS 56855	Between Long Beach and Huntington Beach	84	23 Oct 1984
SIO 87-121	La Jolla Canyon	183	23 Jun 1987
SIO 89-4	14 Mile Bank off Dana Pt.	91	24 Jan 1989
SIO 89-3	North of North Coronado Isl.	122	29 Jan 1989

[a] Hobson 1975
[b] Jones et al. 1985

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IMPROVED SELF-CLEANING SCREEN FOR PROCESSING BENTHIC SAMPLES

Aquatic invertebrates are important waterfowl foods during the breeding (Drobney and Fredrickson 1979, Swanson et al. 1979, Reinecke and Owen 1980) and nonbreeding season (Connelly and Chesemore 1980, Pederson and Pederson 1983, Heitmeyer 1985, Euliss and Harris 1987, Miller 1987). Therefore, waterfowl biologists attempt to quantify invertebrates in waterfowl habitats. Benthic habitats are among the most important micro-habitats sampled in waterfowl investigations. Processing benthic samples is time-consuming because many samples are required, and samples collected with conventional sampling gear (Swanson 1978 and 1983) must be washed to remove small particles of soil and other debris. The transfer of sample residues to collection jars using current procedures is difficult and extreme care is required to avoid spilling samples.

The self-cleaning screen described by Swanson (1977) has been used extensively by waterfowl biologists (Beam and Gruenhagen 1980, Pederson and Pederson 1983, Swanson 1983, Euliss 1984) and it is effective in concentrating sediment cores into sample residues. Samples are transferred from the original screen to a sample jar by placing a corner of the inverted screen on the inside edge of the jar and flushing the residue into the collection jar. The screen contains a 1.3-cm-thick lip that has to be carefully aligned on the lip of a sample jar to avoid spilling the sample. This method is unsatisfactory when samples are

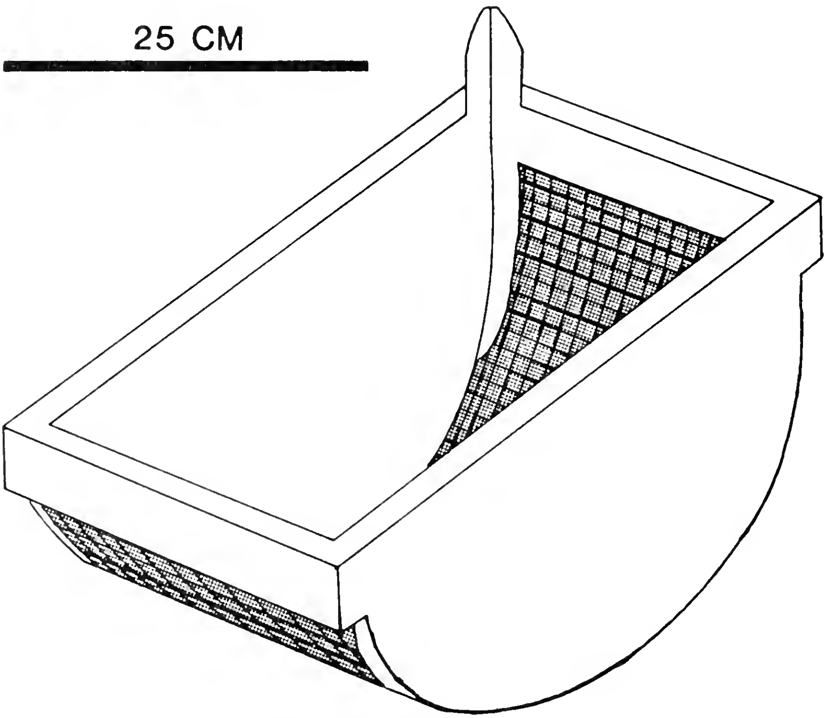

FIGURE 1. Modified self-cleaning screen.

collected from an unstable platform such as a small boat. A modification of the self-cleaning screen described by Swanson (1977) reduces this problem and enables effective transfer of sample residues.

The unit described (Figure 1) in this paper is similar to the initial design (Swanson 1977) with major modifications including an outside coat of fiberglass with an integral pour spout, galvanized hardware cloth to protect the screen and a small tract of fiberglass on an inside corner of the screen surface. The fiberglass tract provides a smooth surface that facilitates transfer of residue. Floatation foam can also be attached to the structure using fiberglass to eliminate the need to periodically replace worn styrofoam. A new coat of resin can restore damaged spouts. Because of the additional strength provided by the fiberglass laminate, the braces described for the original screen (Swanson 1977) are unnecessary.

The improved self-cleaning screen is fabricated by applying fiberglass to the sides of 2 pieces of wood, 38 × 18 cm and 1.6-cm-thick, that have 2 rounded corners. Rigid polyvinyl foam can be used as a substitute if light weight or additional buoyancy is desired. A length of 25-cm-wide screen (0.5 mm) and an outer layer of galvanized hardware cloth is then pressed into resin applied to the bottom edges. Wooden handles are attached to the 2 sides and coated with fiberglass (Figure 1). The pour spout is fabricated separately using the edge of a board covered with wax paper as a mold. After the resin has hardened, the spout is trimmed, allowing a 2.5-cm overlap on the inside of the screen. It is attached with fiberglass. Additional resin is applied to smooth over uneven surfaces created by overlaying the spout. Polyurethane foam strips can be attached to the sides of wooden units using fiberglass to provide additional floatation.

FIGURE 2. Core sample residue being emptied into a collection jar.

After the sediment core is deposited in the screen it is cleaned in the field by moving the apparatus back and forth horizontally just under the water's surface. The sample residue is positioned on the fiberglass tract inside the self-cleaning screen using directional water force with a sweeping action. The pour spout is then inserted into a specimen jar and the sample residue washed into the receptacle using spray from a syringe or wash bottle (Figure 2). This method facilitates transfer of sample residues into collection jars even when sampling from a boat when wave action is moderately severe.

The original screen has proven to be an effective cleaning device and has held up to the rigors of sampling under a wide variety of conditions. The modified version has been used for 2 years. The fiberglass construction provides additional strength that should make the improved screen more durable than the original model.

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