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STATUS OF THE DESERT PUPFISH, *CYPRINODON MACULARIUS* (BAIRD AND GIRARD), IN CALIFORNIA

by

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Inland Fisheries, Region 5

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STATUS OF THE DESERT PUPFISH, *CYPRINODON MACULARIUS* (BAIRD AND GIRARD) IN CALIFORNIA[1/]

by

Glenn F. Black[2/]

ABSTRACT

Evidence from various sources demonstrates that the distribution of the desert pupfish, *Cyprinodon macularius*, has declined in California. The species was once endemic to the Colorado River and numerous springs throughout the Salton Sink, but is presently found only in the Salton Sea and some of its tributaries. Casual observations by numerous individuals indicated that their distribution and numbers within these areas had become severely reduced in recent years, reportedly due to loss of habitat and proliferation of exotic species.

To assess the distribution and relative abundance of desert pupfish, surveys were conducted quarterly at various locations in and around the Salton Sea. Minnow traps were used to sample fish within irrigation drains, shoreline pools, three permanent natural tributaries, and the Salton Sea proper between March 1978 and January 1979. San Felipe Creek, an intermittent tributary to the Salton Sea, was also surveyed in November 1978 and March 1979 following a report by the Bureau of Land Management that pupfish had been observed there.

Thirteen nonnative species of fish and one invertebrate species were collected in addition to the desert pupfish. The latter comprised 3% of the total catch from the four surveys of the irrigation drains, 5% of the catch from the shoreline pools, and less than 1% of the catch from the natural tributaries and the Salton Sea proper. On the other hand, the sailfin molly, *Poecilia latapinna*, accounted for 85% of the total catch in the irrigation drains, 81% of the catch in the shoreline pools, 70% of the catch from the natural tributaries, and 98% of the catch in the Salton Sea proper. The status of the pupfish populations in these habitats seems precarious.

By contrast, desert pupfish made up 70% of the total catch from San Felipe Creek. Although several nonnative species were also present,

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including the sailfin molly, their numbers were low. Thus, San Felipe Creek appears to support a viable population of desert pupfish. Planned agricultural development of several sections of land adjacent to the creek and also land subdivision for housing pose immediate threats to the habitat. Pumping of ground water to supply these developments may eliminate the surface flow in San Felipe Creek.

Because the desert pupfish has undergone a significant reduction in its range, and due to existing threats to the only viable natural population remaining in California, the desert pupfish qualifies for listing as an endangered species under both State and Federal endangered species acts. Cooperation between County, State, and Federal governments as well as the private sector will be necessary to prevent this species from becoming extinct in California.

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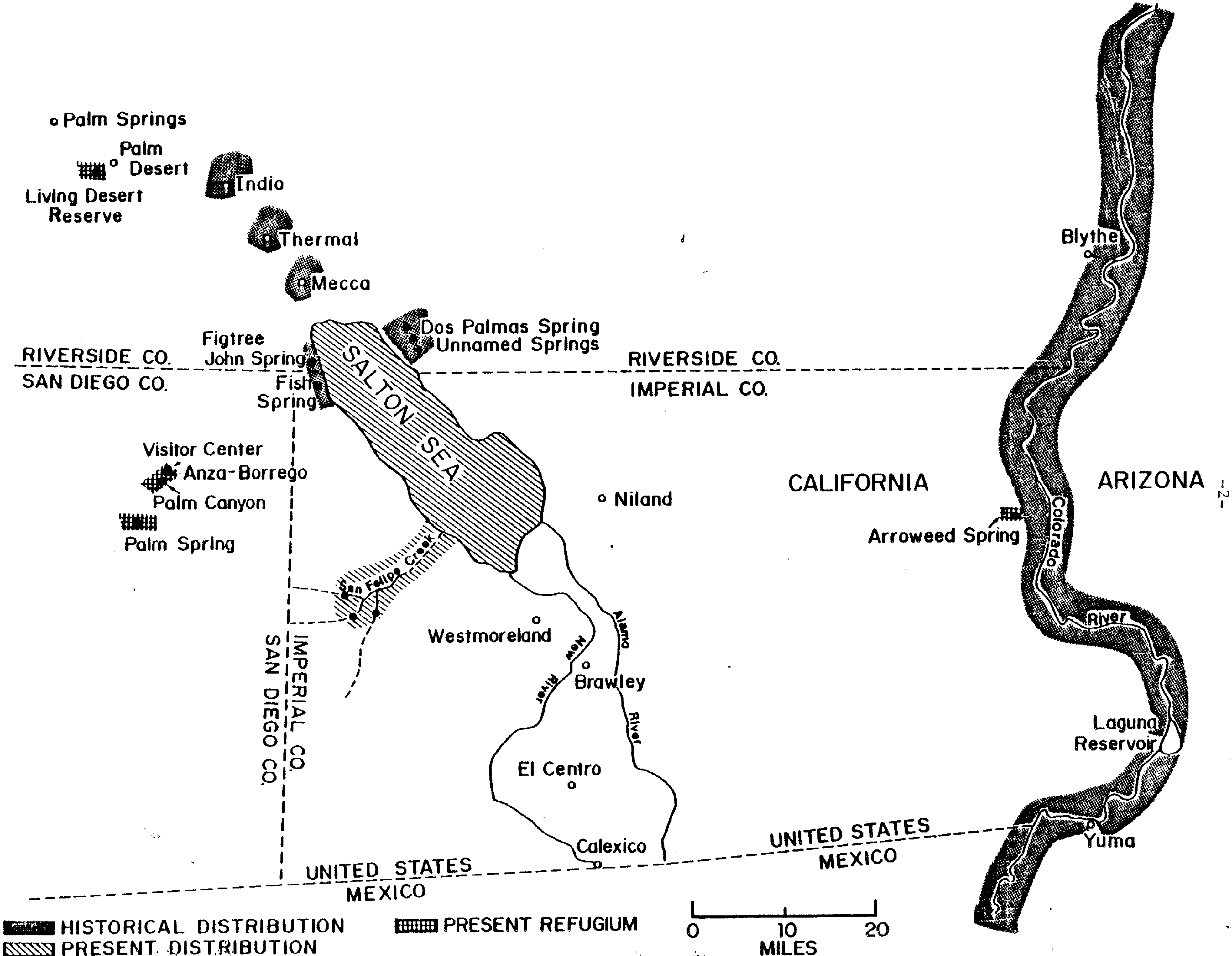
INTRODUCTION

The desert pupfish, *Cyprinodon macularius* (Baird and Girard), a member of the killifish family, is endemic to the backwaters, sloughs, springs, and seeps of the Gila River drainage in Arizona; the Sonoyta River drainage in northern Sonora, Mexico; and the lower Colorado River drainage (including the Salton Sink) of California and Baja California (Miller 1943). Several of these isolated populations of desert pupfish are considered to be separate subspecies (Minckley 1973). The Monkey Springs population in Arizona, probably a distinct species is now considered extinct (Schoenherr, pers. commun. 1979). Several other populations of desert pupfish outside of California are considered to be endangered, threatened, or of "special concern" by the American Fisheries Society (Deacon et al. 1979). Serious declines in these populations are directly related to interferences by man and include: (1) the introduction of exotic predator and competitor species, (2) habitat modification due to water diversions, and (3) ground water pumping for agriculture (Pister 1974).

The desert pupfish was first reported from California in 1859 by Girard who found them in some unnamed saline springs identified only as in Imperial County (Jordan, Evermann, and Clark 1930). Since then this species has been reported from the following locations in California (Figure 1): the Colorado River (Garman 1895, Gilbert and Scofield 1898, Hubbs and Miller 1941); Figtree John Spring (Evermann 1916, Coleman 1929); the Salton Sea (Thompson and Bryant 1920, and numerous authors since); Fish Spring (Thompson 1920, Coleman 1929), Dos Palmas Spring (Eigenmann and Eigenmann 1888, Jaeger 1938); San Felipe Creek (Clark 1930, Miller 1943); artesian wells near Mecca (Miller 1943), Thermal, and Indio (Jordan 1924, Miller 1943); and two unnamed springs near Dos Palmas Spring (Miller 1943).

The desert pupfish has since disappeared from the Colorado River (Colorado River Wildlife Council 1977), and from Dos Palmas Spring and the two unnamed springs nearby (Calif. Dep. Fish and Game, unpubl. data). Two other springs from which pupfish were reported, Fish Spring and Figtree John Spring, no longer exist. Fish Spring has been capped and a mobile home park currently exists in this area (F. Hoover, Calif. Dep. Fish and Game, pers. commun.), and Figtree John Spring has been inundated by the rising of the Salton Sea (pers. observ.). The locations of the artesian wells near Indio, Thermal, and Mecca were never given by Miller (1943), and they could not be found during recent searches by DFG personnel (Calif. Dep. Fish and Game, unpubl. data). Because of the great amount of agricultural development that has occurred in these areas they probably no longer exist, except possibly as capped irrigation wells. Thus, the desert pupfish is no longer found in California in any of its native habitats except certain of the tributaries of the Salton Sea, including San Felipe Creek. The Salton Sea is not a natural body of water, having been formed and now maintained by man's activities.

The desert pupfish has been reported as "abundant" at the Salton Sea by several authors (Coleman 1929; Cowles 1934; Barlow 1958*a*, 1961; Walker 1961), however, only Barlow (1961) attempted to estimate their abundance. He observed schools of juvenile pupfish estimated at 10,000 individuals in a single shoreline pool and approximately 150 adults/m^2 in another.


Palm Springs
Palm Desert
Living Desert Reserve
Indio
Thermal
Mecca
Dos Palmas Spring
Unnamed Springs
Figtree John Spring
Fish Spring
RIVERSIDE CO.
SAN DIEGO CO.
RIVERSIDE CO.
IMPERIAL CO.
SALTON SEA
Visitor Center
Anza-Borrego
Palm Canyon
Palm Spring
San Felipe Creek
Niland
CALIFORNIA
ARIZONA
Blythe
Colorado
River
Arroweed Spring
Westmoreland
New River
Alamo River
Brawley
El Centro
Calexico
IMPERIAL CO.
SAN DIEGO CO.
Laguna Reservoir
Yuma
UNITED STATES
MEXICO
UNITED STATES
MEXICO
HISTORICAL DISTRIBUTION
PRESENT DISTRIBUTION
PRESENT REFUGIUM
0
10
20
MILES

Collections made by California Fish and Game personnel since 1955 (Calif. Dep. Fish and Game, unpubl. data) and others, including Schoenherr (1979), since 1964, indicate that the abundance of desert pupfish at the Salton Sea has severely declined. A possible cause for this may be the introduction and establishment of several exotic tropical species that may prey on or compete with desert pupfish for available food and space, certain of these exotics were probably "escapees" from nearby private fish hatcheries where they were reared for the aquarium trade (J. A. St. Amant, Calif. Dep. Fish and Game, pers. commun.). The sailfin molly was first discovered approximately 23 years ago in irrigation drains. Since then the molly has become established in the Salton Sea (Moyle 1976) along with the shortfin molly, *P. mexicana* (Schoenherr 1979); the porthole fish, *Poeciliopsis gracilis* (Mearns 1975); and the red shiner, *Notropis lutrensis* (Moyle 1976).

In addition, Zill's cichlid, *Tilapia zillii*, and the Mozambique mouthbrooder, *Sarotherodon mossambicus*, have been reported to be established in the Salton Sea by Hoover (1971) and Moyle (1976), respectively[3/]. These two species were introduced in the late 1960's and early 1970's by the local irrigation districts to control aquatic weed growth in the irrigation canals and drains. Since then the Zill's cichlid has been stocked annually in these areas.

Ten years after Barlow (1961) and Walker (1961) had reported the desert pupfish as "abundant" at the Salton Sea, Crear and Haydock (1971) suggested that desert pupfish be reared in the laboratory to supply adequate stocks for sanctuaries and thereby preserve the species from extinction at the Salton Sea. Subsequently, the Department of Fish and Game established desert pupfish from the Salton Sea in five sanctuaries, three within Anza-Borrego Desert State Park, San Diego County, one at Arrowweed Springs, Imperial County, and another at the Living Desert Reserve, Riverside County.

Fisk (1972) recommended that pupfish populations at the Salton Sea be periodically monitored to detect any changes requiring protection for this already depleted species. It was not until 1977 that the Department's Endangered Species Project was finally organized to evaluate the status of various depleted native fishes throughout California. To assess status of the desert pupfish at the Salton Sea, quarterly surveys were initiated by the Department of Fish and Game in March 1978. Two surveys of San Felipe Creek, an intermittent tributary to the Salton Sea, were also conducted. This report presents results of these surveys and makes recommendations for future management of this species.

MATERIALS AND METHODS

Fish populations were sampled with minnow traps made of 0.25-cm wire mesh. Traps were 41 cm long, 23 cm in diameter, and had a 3.8-cm opening at each end of the trap. Traps were baited with canned cat food that had several holes punched in the top of the can and set for approximately 24 h before they were pulled from the water and checked for catch.

[3/] More recent sampling has produced what appears to be another species of African cichlid, possibly *S. aurea*, in the Salton Sea. Identification is pending.

The number of trap sites selected within each irrigation drain, etc., was determined by the diversity in physical habitat types encountered within that specific area. For example, within some irrigation drains only two sites were selected for sampling because there was little habitat diversity (substrates, water depth, water clarity, and types of aquatic vegetation present), while another drain was sampled at 10 sites due to the variety of habitat types found (Appendix 1). A total of 65 minnow traps were set in 18 irrigation drains, 8 traps placed in 2 shoreline pools, 14 traps set in 3 permanent tributaries to the Salton Sea, and 19 traps placed in 13 areas of the Salton Sea proper. Sampling effort was maintained at these levels in each of the quarterly surveys.

The data recorded at each trap site included the following: (1) specific location, (2) date and time trap was set and pulled, (3) water depth, (4) number of various fish species captured, and (5) observations of substrate type and aquatic vegetation.

Dissolved oxygen, temperature, water clarity, and salinity were measured as time permitted at selected sites in irrigation drains, shoreline pools, and tributaries. Dissolved oxygen was measured in parts per million with a YSI (model 51A) meter, water clarity was measured in JTU's with a Hach turbidity meter, and salinity was measured in parts per thousand with a Myron L-DS meter.

The same materials and methods were used in the two surveys of San Felipe Creek except that water quality measurements were not taken. However, in the first survey 18 minnow traps were set along a 6.4-km section of the Creek and in the second survey 8 traps were set along a 3.3-km section of the Creek not sampled in the first survey.

Description of Habitats

Agricultural irrigation drains were sampled on both the northern and southern ends of the Salton Sea (Figure 2). It was felt these drains would contain representative fish populations. They varied in length from 55 to 4,000 m and in width from 1 to 5 m (Appendix 1). Water depth, clarity, salinity, and dissolved oxygen varied greatly between and within individual drains (Appendices 1 and 2).

Shoreline pools sampled during the quarterly surveys were located on the southern and eastern portions of the Salton Sea (Figure 2). These pools were areas of standing Salton Sea water partially separated from the Salton Sea proper by bars of either barnacles, or sand built by wave action. They were irregular in shape, ranging from 25 to 1,000 m in length, 5 to 50 m in width, and 5 to 61 cm in depth (Appendix 3). Because they were partly isolated from the main body of the Salton Sea and relatively shallow, the salinity of these pools sometimes was two to three times higher than the Sea proper (Barlow 1958*b*). Daily water temperatures could fluctuate as much as 15 to 20°C in shallow pools during the summer (Barlow 1958*a*) and reach as high as 43°C (pers. observ.), the reported critical thermal maximum for desert pupfish (Low and Heath 1969). The shoreline pools lacked rooted aquatic vegetation, but algae were present. Terrestrial vascular plants were also present, having been inundated by the rising level of the Salton Sea. The substrate of the shoreline pools consisted of silt and decaying organic matter. Five

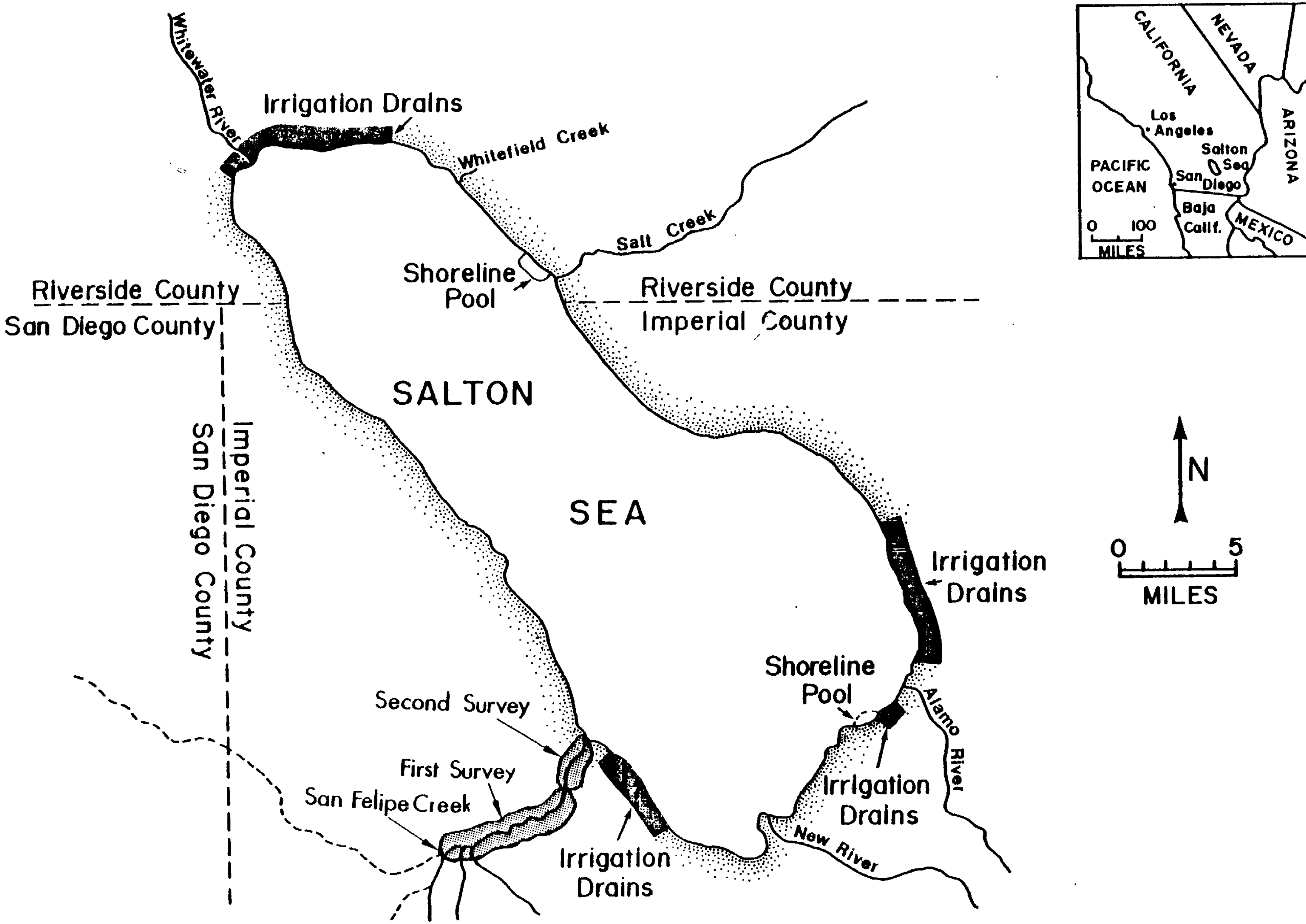


FIGURE 2. Areas sampled during desert pupfish surveys.

shoreline pools were sampled during the spring survey, however, water evaporation during the summer and fall resulted in the temporary loss of three shoreline pools.

The permanent tributaries sampled in the quarterly surveys were located in the northern, northeastern, and eastern portions of the Salton Sea (Figure 2). With the exception of Whitefield Creek, only a small portion near the mouths was sampled. These tributaries varied in relation to water depth, clarity, and salinity (Appendix 2). The amount of surface flow, type of substrate, and kinds of aquatic vegetation varied between tributaries. Whitefield Creek and Salt Creek are natural drainages with natural flows while the Whitewater River consists primarily of irrigation runoff in the areas sampled (Figure 2).

San Felipe Creek, the intermittent tributary sampled in two separate surveys, is located at the southwestern end of the Salton Sea (Figure 2). Springs provide a year round flow for the first 7.2 km, but the remainder of the Creek (8 km) is intermittent, connecting to the Salton Sea only during and after periods of heavy rainfall. The normal surface flow is minimal and the total dissolved solids range from 8,000 to 10,000 ppm (Brown 1923). The substrate varies from sand-silt to quicksand.

The areas of the Salton Sea proper sampled in the quarterly surveys were at the northern and northeastern portions of the Salton Sea (Figure 2). Traps were set near the mouths of the irrigation drains and off the sand and barnacle bars associated with the shoreline pools. The Salton Sea lacked rooted aquatic plants but terrestrial vascular plants were present in the nearshore areas due to inundation from the rising level of the Salton Sea. The substrate in these areas was either densely packed barnacles, or soft mud. The salinity was that of Salton Sea water which varied, depending upon the time of year, from 36 to 38 $^{o}/oo$.

RESULTS

Irrigation Drains

A total of 13 species of fish and 1 invertebrate species was captured during the surveys of the irrigation drains (Appendix 1). The most abundant species was the sailfin molly, which accounted for 73%, 90%, 86%, and 73% of the catch in the spring, summer, fall, and winter surveys, respectively (Figure 3). This species comprised 85% of the total catch from the four surveys combined (Figure 3). The sailfin molly was most numerous in the summer survey, when almost 4,000 were captured; this was 2.5 times more than in the fall survey and 5 times more than in the spring and winter surveys (Figure 3). This species also had the widest distribution since it occurred in at least 14 drains on each survey and overall was sampled from 17 of the 18 drains surveyed (Appendix 1).

African cichlids were the next most abundant fish sampled (Figure 3). Taxonomic identification of Zill's cichlid and the Mozambique mouthbrooder can only be determined by counting gill rakers. Since the minnow traps were selective for only the juveniles (fish less than 7.6 cm TL), both species were tabulated together in this report. The adults of the two species can be easily distinguished

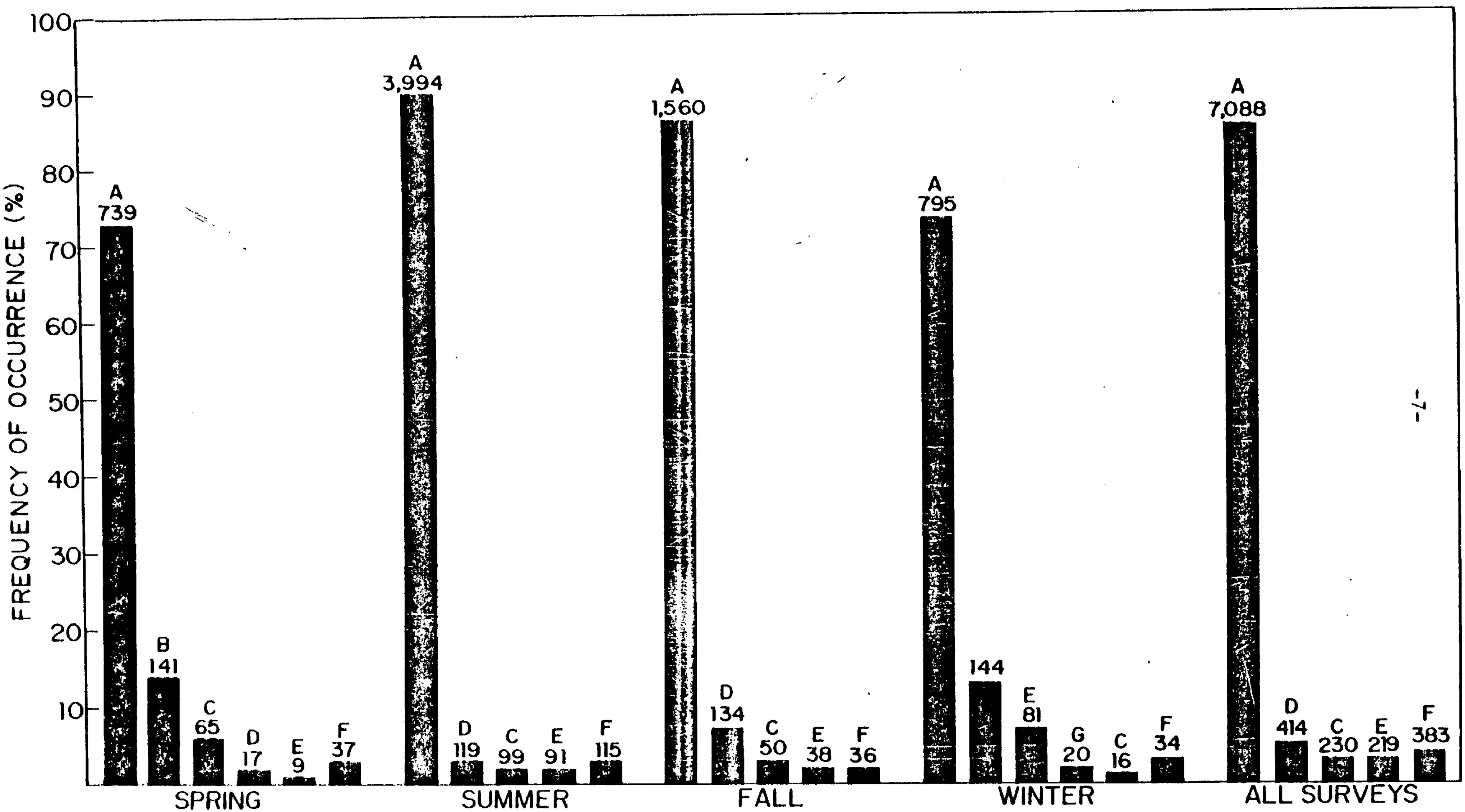


FIGURE 3. Seasonal distribution of species captured in 18 irrigation drains during desert pupfish surveys at the Salton Sea. Numbers above the bars refer to total number captured. A = sailfin mollies, B = red shiners, C = crayfish, D = African cichlids, E = desert pupfish, F = other species, G = shortfin mollies.

based on coloration. It was noted that all adult African cichlids observed in the irrigation drains were Zill's cichlids. Thus, it is probable that the majority, if not all the cichlids captured were Zill's cichlids. African cichlids contributed to 2% of the catch in the spring survey, 3% in the summer survey, 7% in the fall survey, 13% in the winter survey, and 5% of the combined catch from the four surveys (Figure 3). The number sampled was relatively constant during the summer (119), fall (134), and winter surveys (144), however, they were extremely low in the spring survey (17) (Figure 3). These fish were also the second most widely distributed species sampled throughout the irrigation drains occurring in as many as 12 drains during the fall survey to as few as five drains during the spring survey and overall were sampled from 16 drains (Appendix 1).

The crayfish, *Procambarus clarkii*, made up 2% of the catch in the spring and summer surveys, 3% in the fall survey, 1% in the winter survey, and 3% of the combined catch from the irrigation drains (Figure 3). Crayfish were most numerous in the summer survey when 99 were captured and least numerous in the winter survey when only 16 were found (Figure 3). Their distribution was limited to as few as three irrigation drains during the fall survey and to as many as seven during the spring and summer surveys; crayfish were found in 10 different irrigation drains during the four surveys (Appendix 1).

The desert pupfish accounted for only 1% of the catch in the spring survey, 2% in the summer and fall surveys, 7% in the winter survey, and 3% of the catch from all four surveys (Figure 3). They were most numerous in the summer survey when 91 were sampled and least numerous in the spring when only nine were taken (Figure 3). Their distribution was restricted to as few as three irrigation drains in the winter survey and to as many as eight in the summer survey but overall they were found in 15 of the 18 irrigation drains sampled (Appendix 1).

The ratios of potential predator and competitor species to desert pupfish within the irrigation drains indicated that the relative abundance of pupfish varied tremendously from one drain to the next on any of the surveys and that some variability existed within different habitats of an individual drain (Table 1). With the exception of Vail 3-A and Niland 5 drains, desert pupfish were outnumbered by potential predator and competitor species at every site where pupfish were captured (Table 1).

There were a wide variety of habitat types represented in the drains sampled, and much variation existed between and even within each drain. Sailfin mollies and African cichlids showed no preference for specific habitats, but seemed to be distributed throughout the habitats in any particular drain. On the other hand, desert pupfish seemed to prefer drain areas having a sand-silt substrate with either rooted or unattached aquatic plants, and a very restricted surface flow. Dissolved oxygen monitored at sites where desert pupfish were trapped varied from a low of 1.2 ppm to a high of 7.2 ppm (Appendix 2). Pupfish did not appear to select any particular dissolved oxygen level. Turbidity measurements taken at 28 locations where desert pupfish were sampled showed that they preferred water clearer than 75 JTU's (Appendix 2). They were found in salinities ranging from 2,300 to 27,000 ppm with no apparent preference (Appendix 2). With the exception of Vail 3-A drain, 89% of the pupfish were captured in water less than 30 cm, however, in this drain 90% of the pupfish trapped were in water greater than 30 cm (Appendix 2).

TABLE 1. The Ratios of Potential Predator and Competitor Species to Desert Pupfish as Sampled in Individual Traps Within 15 Irrigation Drains During Quarterly Serveys in the Salton Sea.[1/]

Drain	Spring	Summer	Fall	Winter
Arthur		204:1	66:1	19:1
Ave. 73	56:1			
Ave. 76	20:1	14:1		
Barth			14:1	3:1
Grant			19:1	
Hayes			40:1	
Niland 1		2:1		
Niland 5	12:1	1:1		
Trifolium 7-A	12:1			
"U"		17:1		
Unnamed	23:1			
Vail 3-A		1:8	1:1	1:28
Vail 4-A	34:1			
Wheeler		325:1 265:1	9:1 70:1 104:1	
"Z"		11:1 17:1		

[1/] Ratios are given only where both pupfish and potential predator/competitor species were found within the same trap.

The depth of capture may not have much significance since Barlow (1958*a*) has shown that there is considerable daily movement of desert pupfish in the water column due to temperature preferences, at least in the shoreline pools. There is reason to suspect that daily pupfish movements, in relation to water temperature, also occur in the various depths present in many of the irrigation drains. Courtois and Hino (1979) have demonstrated that desert pupfish prefer water 18-cm to 22-cm deep for egg deposition, so that at least during the breeding season the depth of water available to them is important.

Ten other species were captured in the irrigation drains, but they represented only 4% of the total catch from the four surveys. These species were bluegill, *Lepomis macrochirus*; yellow bullhead, *Ictalurus natalis*; carp, *Cyprinus carpio*; Gulf croaker, *Bairdiella icistia*; mosquitofish, *Gambusia affinis*; longjaw mudsucker, *Gillichthys mirabilis*; shortfin molly, *Poecilia mexicana*; porthole fish, *Poeciliopsis gracilis*; red shiner, *Notropis lutrensis*; and threadfin shad, *Dorosoma petenense* (Table 1, Appendix 1). Carp, Gulf croaker, yellow bullhead, bluegill, and porthole fish were found in only one drain, while longjaw mudsuckers were collected from a total of 12 drains (Appendix 1). Threadfin shad, shortfin mollies, mosquitofish, and red shiners were sampled from a total of two, three, four, and six drains, respectively (Appendix 1). Traps were selective against mosquitofish because they were observed in greater numbers and in more areas than the collection data indicate. Mosquitofish feed primarily at or near water surface, but the traps were rarely set so shallow that trap openings were at or just below the surface.

Shoreline Pools

Five species of fish were sampled from two shoreline pools during the quarterly surveys (Appendix 3). The sailfin molly was the most abundant species sampled during the spring, summer, and fall surveys when it made up 85%, 89%, and 90% of the catch, respectively; during the winter survey it accounted for only 1% of the fish sampled (Figure 4). The combined catches of all four surveys showed that the sailfin molly was the most abundant species contributing to 81% of the total catch from the shoreline pools (Figure 4). Unlike the findings in the irrigation drains where sailfin mollies were most numerous during the summer survey, it was found that they were most numerous in the shoreline pools during the fall survey (Figure 4). The 857 sailfin mollies captured in the fall survey were twice as many as in the summer survey and three times more than in the spring survey (Figure 4).

The longjaw mudsucker was the next most abundant species in the shoreline pools making up 13% of the combined catches of the four surveys (Figure 4). By contrast, African cichlids were the second most abundant fish sampled from the irrigation drains. The longjaw mudsucker accounted for 3% of the catch in the spring survey, 5% in the summer, 8% in the fall, and 78% in the winter (Figure 4). It was most numerous in the winter survey, when 134 were sampled and least numerous in the spring survey, when only 10 were found (Figure 4). This species was sampled from only one of the two shoreline pools throughout the quarterly surveys (Appendix 3).

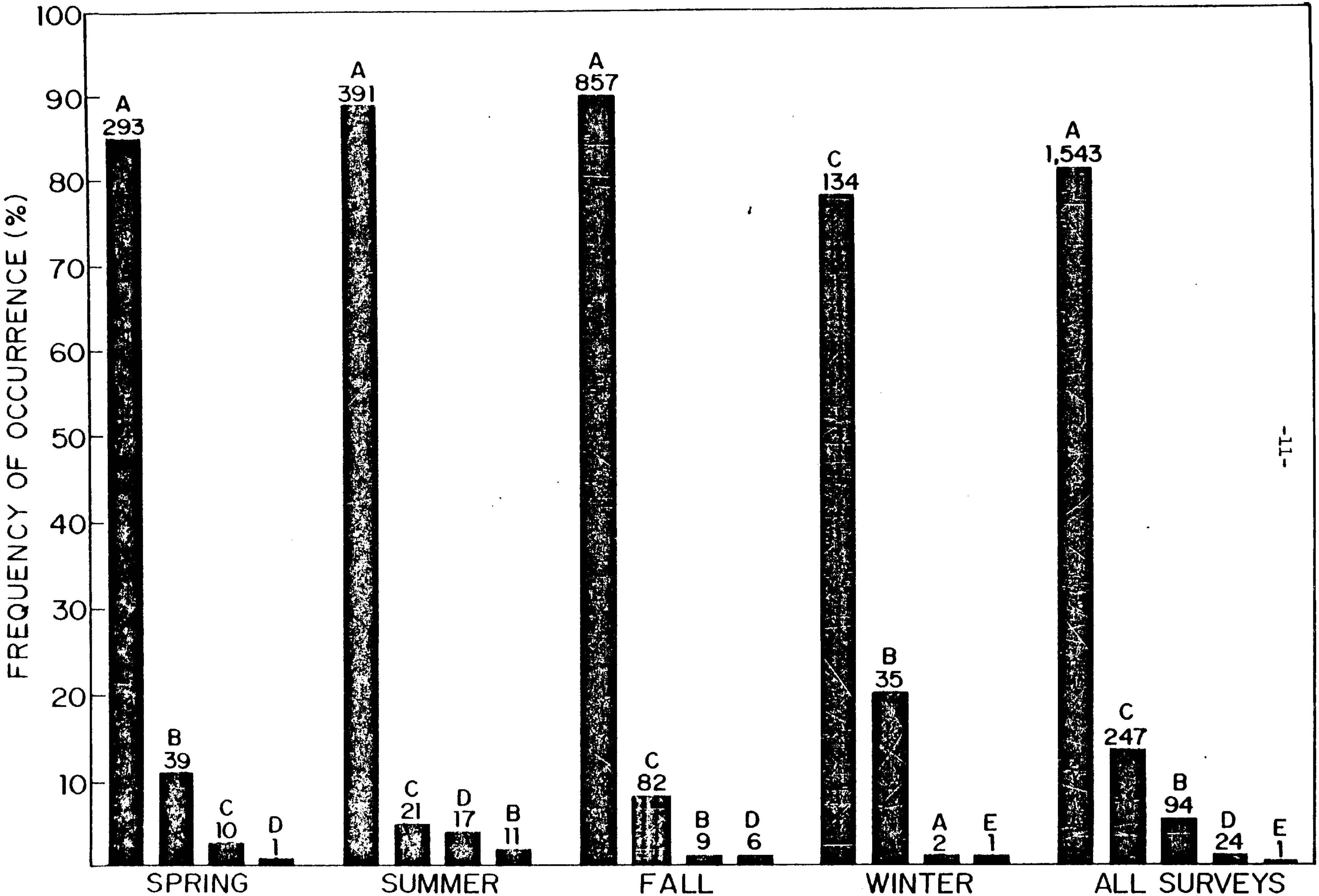


FIGURE 4. Seasonal distribution of species captured in two shoreline pools during desert pupfish surveys at the Salton Sea. Numbers above the bars refer to total number captured. A = sailfin mollies, B = desert pupfish, C = longjaw mudsucker, D = African cichlids,

Desert pupfish contributed to 11% of the catch in the spring, 2% in the summer survey, 1% in the fall survey, 20% in the winter survey, and 5% of the total catch for all four surveys (Figure 4). Pupfish were most numerous in the spring survey, when 39 were sampled and least numerous in the fall survey, when only nine were sampled (Figure 4). The pupfish was found in both shoreline pools during the spring, summer, and fall surveys, but found in only one of them during the winter survey (Appendix 3).

The ratios of potential predator and competitor species to desert pupfish at separate trap sites in each of the shoreline pools shows some variability from one site to another within the same shoreline pools and a great amount of variability in abundance between the two pools during the same surveys (Table 2). Based upon this ratio data, it is also apparent that pupfish were consistently more abundant in the Salton Sea National Wildlife Refuge pool than Salt Creek pool (Table 2).

African cichlids and shortfin mollies represented the remaining 1% of the total catch from the four surveys of the shoreline pools (Figure 4). A total of 24 cichlids were captured during the spring, summer, and fall surveys, while the one shortfin molly was sampled during the winter survey (Figure 4).

Natural Tributaries

Nine fish species and one invertebrate species were captured during the quarterly surveys of Salt Creek, Whitefield Creek, and the Whitewater River (Appendix 4). As in the surveys of the irrigation drains and the shoreline pools, the sailfin molly was the most abundant species captured, comprising 85% of the species sampled in the spring, 69% in the summer, 68% in the fall, 61% in the winter, and 70% of the total catch from all the surveys (Figure 5). Sailfin mollies were most numerous in the traps during the summer survey, when 866 were collected and least numerous during the winter survey, when only 84 were taken (Figure 5). This was similar to seasonal fluctuations in abundance within the irrigation drains. Sailfin mollies were captured in each of the tributaries during every survey with the exception of the winter survey of Salt Creek (Appendix 4).

Similar to the irrigation drains, African cichlids were the next most abundant species sampled from the natural tributaries, making up 2% of the catch in the spring, 11% in the summer, 14% in the fall, 4% in the winter, and 10% from all the surveys combined (Figure 5). They were most numerous in the summer survey, when 137 were captured and least numerous in the spring survey, when only four were captured (Figure 5). African cichlids were sampled from all three tributaries during three of the surveys conducted (Appendix 4).

The red shiner represented 9% of the total catch from all four surveys of the tributaries (Figure 5). However, 175 of the 178 red shiners collected during the summer survey were from the Whitewater River (Figure 5, Appendix 4).

The longjaw mudsucker accounted for 11% of the catch during the spring, 4% during the summer, 14% during the fall, 13% during the winter, and 6% of the total catch (Figure 5). Mudsuckers were most numerous in the tributaries during the summer survey when 49 were caught and least numerous during the winter survey when only 18 were captured (Figure 5). They were taken from all three tributaries surveyed (Appendix 4).

TABLE 2. The Ratios of Potential Predator and Competitor Species to Desert Pupfish as Sampled in Individual Traps Within Two Shoreline Pools During Quarterly Surveys at the Salton Sea.

Shoreline pool	Ratio of predators/competitors to desert pupfish			
	Spring	Summer	Fall	Winter
Salt Creek	14:1	58:1 47:1	188:1	
Salton Sea National Wildlife Refuge	2:1 1:2	7:1 7:1	15:1 55:1	1:14

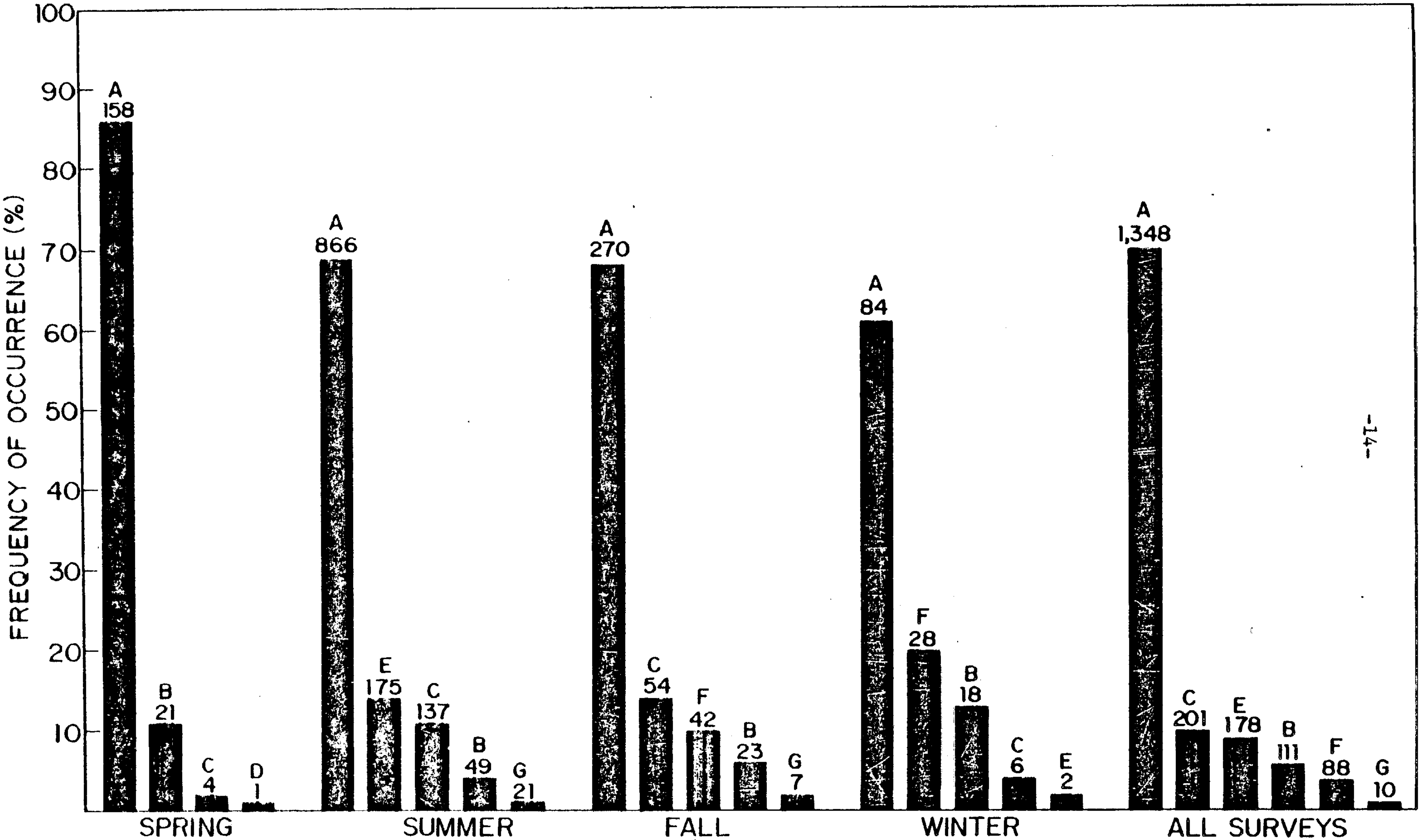


FIGURE 5. Seasonal distribution of species captured in three tributaries to the Salton Sea during desert pupfish surveys. Numbers above the bars refer to total number captured. A = sailfin mollies, B = longjaw mudsuckers, C = African cichlids, D = crayfish, E = red shiners, F = shortfin mollies, G = other species.

Shortfin mollies contributed to 4% of the total catch from the quarterly surveys of the tributaries (Figure 5). They were found in the tributaries during the summer, fall, and winter surveys and comprised 20% of the catch during the winter survey (Figure 5, Appendix 4).

Five other species, including the desert pupfish, Gulf croaker, carp, mosquitofish, and crayfish were sampled from the tributaries during the quarterly surveys, but together they made up only 1% of the catch (Figure 5, Appendix 4). Only five desert pupfish were taken from the tributaries: three from Salt Creek during the summer survey and two from Whitefield Creek during the fall (Appendix 4).

Salton Sea Proper

Six species of fish were collected from 13 areas in the Salton Sea (Appendix 5). As in the surveys of the irrigation drains, shoreline pools, and the tributaries, the sailfin molly was the most abundant species captured in the Salton Sea proper, making up 98% of the combined catch from all four surveys (Figure 6). This species represented 100% of the catch from the spring survey, 98% from the summer, 99% from the fall, but only 28% from the winter survey (Figure 6). Sailfin mollies were most numerous in the summer survey when 1,356 were captured and least numerous in the winter survey when only five were taken (Figure 6). Their distribution was limited to three sampling areas of the Salton Sea in the spring and winter surveys, but they were found in all 13 sampling locations during the fall survey (Appendix 5).

Juvenile orangemouth corvina, *Cynoscion xanthulus*, were the next most abundant species captured in the four surveys of the Salton Sea proper (Figure 6). They made up 1% of the total catch and were taken only during the spring and summer surveys in which they accounted for 1% and less than 1% of the catch, respectively (Figure 6). They were sampled from the mouths of three irrigation drains and off one sandbar (Appendix 5).

African cichlids, Gulf croakers, desert pupfish, and longjaw mudsuckers made up the remaining 1% of the total fish captured in the surveys of the Salton Sea proper (Figure 6). However, the only desert pupfish captured was off the mouth of Hayes Street drain during the winter survey (Appendix 5).

Summary of the Results of the Quarterly Surveys

The surveys of the irrigation drains, shoreline pools, natural tributaries, and the Salton Sea proper clearly show that the sailfin molly was the most abundant and widely distributed of all the species sampled. Only during the winter survey of the shoreline pools and the Salton Sea proper was the sailfin molly not the most abundant species captured; in both cases the longjaw mudsucker was the most abundant species (Figures 4 and 6). The probable reason for the mudsucker being more numerous than the sailfin molly in these two habitats was because of the occurrence of a large die-off of mollies several weeks before the winter survey (pers. observ.). Although I did not record water temperatures from the Salton Sea during this survey, this may have been due, in part, to colder than normal water in these areas, whereas water in the irrigation drains stays warmer during the winter due to the subsurface flow of irrigation return water (Appendix 2). Sailfin mollies contributed to 78% of the total catch from all habitats sampled during the spring survey, 89% for the summer survey, 88% for the fall survey,

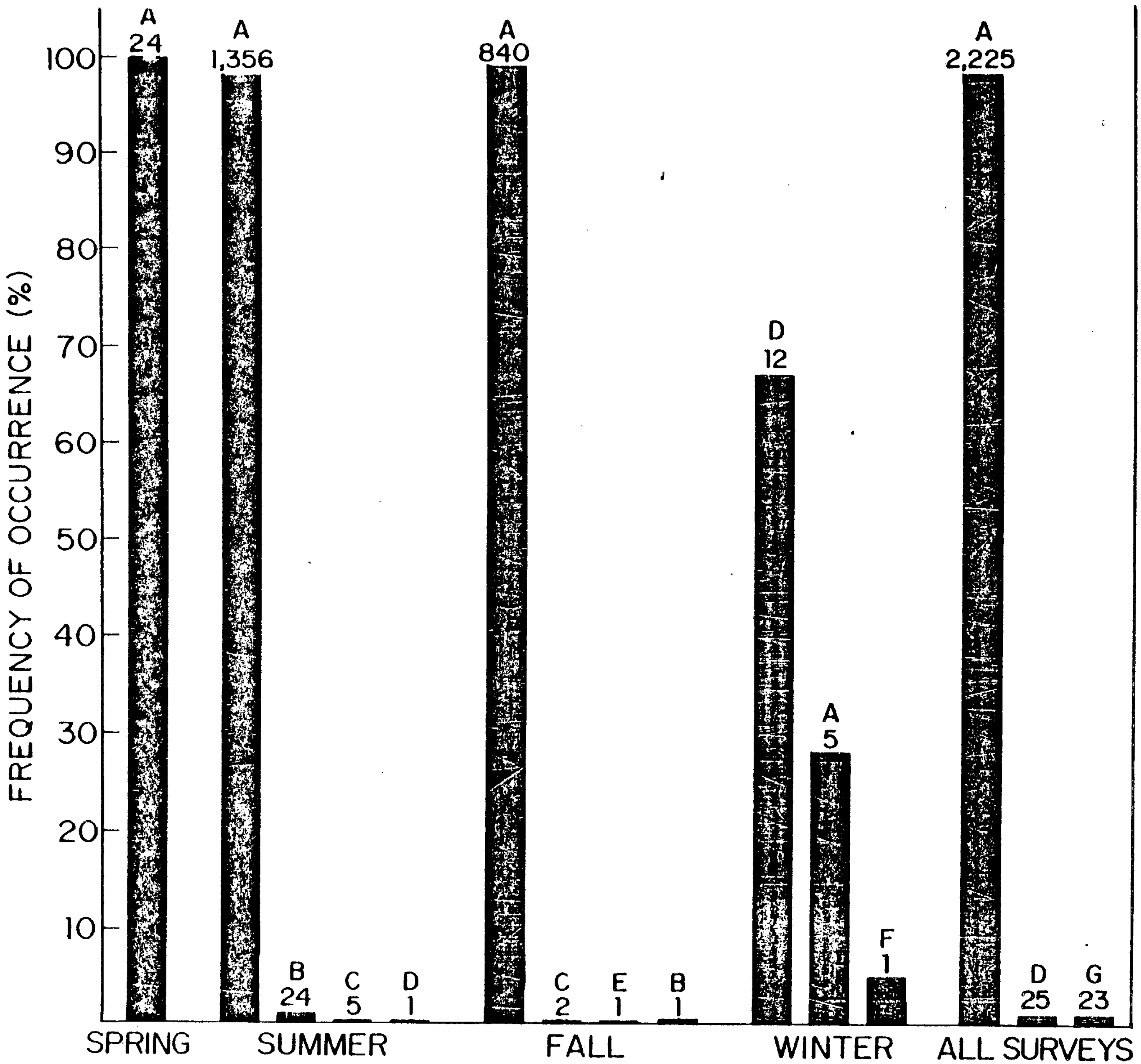


FIGURE 6. Seasonal distribution of species captured in 13 areas of the Salton Sea proper during desert pupfish surveys. Numbers above the bars refer to total number captured. A = sailfin mollies, B = orangemouth corvina, C = African cichlids, D = longjaw mudsuckers,

and 63% for the winter survey (Figure 7). Overall, the sailfin molly accounted for 85% of the 16,048 fish and invertebrates collected during the quarterly surveys of the four habitat types (Table 3). Substantial variability occurred in the numbers of sailfins captured seasonally from the four habitats sampled (Figures 3 to 7). Relative abundance showed less seasonal variability (Figures 3 to 7).

African cichlids, longjaw mudsuckers, and red shiners contributed to 4%, 3%, and 2%, respectively, of the total catch from the four habitats sampled (Table 3). Large fluctuations in numbers and relative abundance were noted for these species based on habitat type and/or season (Figures 3 to 7).

A total of 324 desert pupfish were captured during the four surveys and they made up 2% of the total catch (Table 3). Moderate seasonal fluctuations in the numbers of desert pupfish sampled and their relative abundance were noted within habitat types (Figures 3 to 6). Considerable variation was even noted in relative abundance figures within a specific area (e.g., three sample sites in Wheeler Drain during the fall survey, Table 1).

Crayfish and shortfin mollies accounted for 2% (276) and 1% (141) of the total catch, respectively (Table 3). Moderate seasonal fluctuations in their numbers and relative abundance were also observed within the various habitats (Figures 3 to 7), but the numbers of those species captured was too few to be of significance.

Eight species made up the remaining 1% of the total catch from all the habitats during the quarterly surveys (Table 3). These species were the orangemouth corvina, mosquitofish, porthole fish, threadfin shad, Gulf croaker, yellow bullhead, and the bluegill (Table 3).

Surveys of San Felipe Creek

In contrast to the quarterly surveys, desert pupfish were the most abundant species in San Felipe Creek, making up 70% of the 421 fish captured (Appendix 6). Sailfin mollies constituted 26%, mosquitofish 3%, and shortfin mollies 1% of the total catch (Appendix 6). Pupfish were found along the upper 7.2 km stretch of creek in the fall and along the entire 9.7 km of permanent water in the winter. However, only areas unsampled during the fall survey were sampled during the winter (Figure 2).

The ratios of potential predator and competitor species to desert pupfish were highly variable from one area of the creek to another (Table 4), as they were in the irrigation drains ranging from 8:1 to 1:27 (Table 4).

Refugia Populations

Desert pupfish populations within refugia were not sampled during the Salton Sea and San Felipe Creek surveys, however, information concerning their location, date of establishment, number of fish introduced, and size should be noted.

The first refugium established was at Palm Canyon, San Diego County, within Anza-Borrego Desert State Park. Fifty desert pupfish from the Salton Sea were introduced in June 1970 into a 60' x 15' x 3' concrete pond.

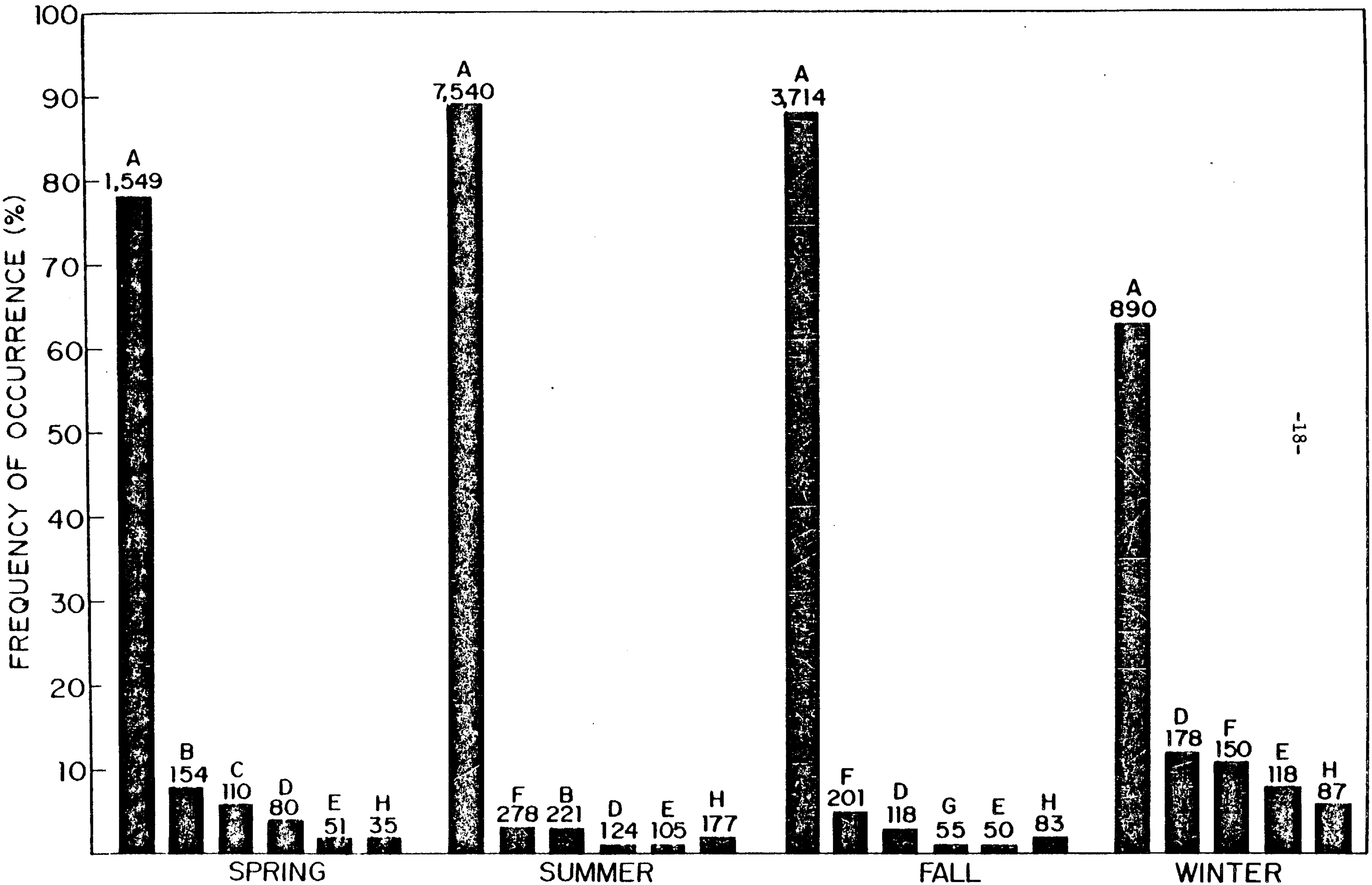


FIGURE 7. Seasonal distribution of species captured from all habitats sampled during desert pupfish surveys at the Salton Sea. Numbers above the bars refer to total number captured. A = sailfin mollies, B = red shiners, C = crayfish, D = longjaw mudsuckers, E = desert

TABLE 3. Numbers and Percent Composition of Each Species Captured From All Habitats During Quarterly Desert Pupfish Surveys at the Salton Sea.

Common name	Scientific name	Number	Percent
Sailfin molly	*Poecilia latapinna*	13,693	85
African cichlids	*Tilapia/Sarotherodon* sp.	641	4
Longjaw mudsucker	*Gillichthys mirabilis*	500	3
Red shiner	*Notropis lutrensis*	399	2
Desert pupfish	*Cyprinodon macularius*	324	2
Crayfish	*Procambarus clarkii*	276	2
Shortfin molly	*Poecilia mexicana*	141	1
Orangemouth corvina	*Cynoscion xanthulus*	25	>1
Mosquitofish	*Gambusia affinis*	22	>1
Porthole fish	*Poeciliopsis gracilis*	16	>1
Carp	*Cyprinus carpio*	3	>1
Threadfin shad	*Dorosoma petenense*	3	>1
Gulf croaker	*Bairdiella icistia*	2	>1
Yellow bullhead	*Ictalurus natalis*	2	>1
Bluegill	*Lepomis macrochirus*	1	>1
		16,048	

TABLE 4. The Ratios of Potential Predator and Competitor Species to Desert Pupfish in Individual Traps Within San Felipe Creek During the Fall Survey.

Number predators/competitors	Number pupfish	Ratio of predators/competitors to desert pupfish
15	2	8:1
49	10	5:1
5	3	5:3
11	10	1:1
8	16	1:2
2	6	1:3
23	93	1:4
2	27	1:14
1	27	1:27

Forty desert pupfish were introduced into a 10' x 2' circular concrete pond at the Living Desert Reserve, Riverside County, during 1972. These fish originated from the refugium population at Palm Canyon and were introduced by Department personnel.

Another refugium was established in September 1975 in Arrowweed Spring (Imperial County), a concrete wildlife drinker. Twenty-five desert pupfish were introduced from the Salton Sea into this 10' x 10' x 3' refugium by Department personnel. A portion of this drinker is capped and only a 3' x 10' section is exposed.

A second pupfish refugium was established in Anza-Borrego Desert State Park at Palm Spring in May 1978. Forty-five desert pupfish were introduced from the Palm Canyon Refugium to a clover-shaped concrete pond that measures roughly 20' long x 8' wide. The depth varies from a spawning shelf 8 in. deep to the remainder of the pond which is 24 in. deep. The water source for the pond is a natural spring.

The most recent refugium established was also within Anza-Borrego Desert State Park, at the Visitor Center. Thirty desert pupfish from the Salton Sea and 20 from Palm Canyon Refugium were introduced in April 1979 into an irregular-shaped concrete pond 20' long x 8' wide. The depth of the pond varies from a 4 in. deep spawning shelf to the major portion which is 18 in. deep.

DISCUSSION

Salton Sea Populations

Although quantitative data are lacking, the desert pupfish was regarded by various observers as "abundant" at the Salton Sea, especially in shallow shoreline pools in 1961. However, this survey of the shoreline pools has shown that the abundance of desert pupfish was low and that the sailfin molly has apparently displaced the pupfish and become the dominant littoral inhabitant. Harrington and Harrington (1961) indicated that food items of the sailfin molly and *C. variegatus*, a close relative of the pupfish, were similar in a subtropical salt marsh. It is probable that the food habits of the sailfin molly and desert pupfish are also similar, but further work needs to be done to establish that competition exists.

The ability of sailfin mollies to withstand high salinities such as occur in the shoreline pools has also been documented (Barlow 1958*b*). Schoenherr (1979) speculates that dramatic rises in the level of the Salton Sea since 1975 may have interfered with nesting of desert pupfish and favored reproduction of sailfin mollies, but I believe the principal factor causing a significant decline in pupfish numbers and distribution within the shoreline pools is more likely to have been direct competition with the sailfin molly for food and living space.

My surveys show that the longjaw mudsucker is more abundant than the desert pupfish within shoreline pools. Walker (1961) reported that mudsuckers occasionally eat pupfish, however, he found no evidence that pupfish numbers were affected by their presence.

Surveys of the irrigation drains show that desert pupfish numbers also were low in this habitat and that the sailfin molly was again the most abundant species sampled. African cichlids and crayfish were also more abundant than desert pupfish in the irrigation drains.

Nichols (Cal Poly, Pomona, pers. commun.) and Cox (1972) showed that juvenile Zill's cichlid and desert pupfish have similar food preferences. Nichols also found as much as 24.6% of the diet of adult Zill's cichlids consisted of unidentified fish and their eggs in one of the irrigation drains at the Salton Sea. Thus, this species may also prey on desert pupfish as well as compete with it for food. Laboratory and field studies of interactions between desert pupfish and Zill's cichlids during the spawning season of the former, indicate that the male pupfish expends significantly more time defending a nest when Zill's cichlids are present than when they are not (M. Matsui, Occidental College, pers. commun.). This behavioral interference resulted in the eggs being unguarded for short periods of time, thus being more susceptible to predation. Similar effects were demonstrated for molly-pupfish interactions.

Schoenherr (1979) states that in an area of one irrigation drain where pupfish formerly abounded, Zill's cichlids are now common. Though this species was not introduced into the irrigation drains until 1971 (Moyle 1976) and thus may not have been directly responsible for the decline of the desert pupfish, evidence from the quarterly surveys and the previously mentioned sources indicates that the cichlid may be helping to keep desert pupfish populations depressed.

Since crayfish also were more abundant in the irrigation drains than pupfish and have been identified as predators of demersal fish eggs (G. Capelli, College of William and Mary, pers. commun.), they also may be limiting pupfish numbers and distribution. Pister (Calif. Dep. Fish and Game, Bishop, pers. commun.) believes crayfish and mosquitofish are responsible for the recent elimination of the Owens pupfish, *C. radiosus*, from a refugium in Warm Springs near Big Pine, California.

Despite the fact that mosquitofish were sampled in very small numbers from the irrigation drains and tributaries to the Salton Sea, they were more numerous than the traps indicated. Their diet has been described by several authors (Harrington and Harrington 1961, Walters 1976) and is much like that of the desert pupfish (Walters 1976, Moyle 1976). Minckley and Deacon (1968) and Deacon and Bunnel (1970) stated that the introduced mosquitofish has been responsible for eliminating many cyprinodonts in the southwest. It is doubtful whether mosquitofish alone have had much of an impact on resident desert pupfish populations at the Salton Sea. Both species were reported as "quite abundant" from the shoreline pools along the shore and in one nearby spring by Coleman in 1929, long before pupfish numbers were on the decline. Also, there are several populations of *C. n. amargosa* and *C. n. nevadensis* that coexist with mosquitofish (E. P. Pister, pers. commun.). However, together with the sailfin molly, Zill's cichlid, and the crayfish all four species probably compete for food, space, and possibly even prey upon the desert pupfish or their eggs to the extent that pupfish abundance and distribution have declined to a precariously low level. Without comparable survey data before 1978, it is impossible to say whether desert pupfish populations will remain at present levels or decline further.

San Felipe Creek Population

The only viable population of desert pupfish remaining in California is within the 7.2 km to 9.7 km of permanent water along San Felipe Creek fed by several desert springs. This is the only natural habitat within the historical range of this species which currently supports a pupfish population. There are some exotic species (sailfin molly, shortfin molly, and the mosquitofish) present in the Creek, but presently they are not abundant. These exotics probably gained access to the permanent water during periods of heavy rainfall when flooding occurs that connects this portion of San Felipe Creek to the Salton Sea. These exotics also successfully reproduce in the Creek, but presently makeup only a minor percentage of the fishery. At present it appears this natural desert creek is marginal habitat for the exotic species. Installation of a low spillway or drop 15 to 30 cm high would prevent further upstream movement of unwanted exotic fish species. Maintenance of the barrier to remove siltation would be necessary every spring.

The National Park Service designated the marsh areas within the San Felipe Creek as a National Natural Landmark in 1971, and in 1974 the Heritage Conservation and Recreation Service identified lower San Felipe Creek as one of the last natural streams in the Colorado Desert. The U. S. Bureau of Land Management (BLM) has designated this land as the San Sebastian Marsh Outstanding Natural Area (Figure 8), and recommended in its Yuha Desert Management Framework Plan (1975) that 12 sections of private land within the natural area be acquired "in order to maintain the integrity and long-term stability of these environmentally sensitive areas". Currently BLM manages public lands in the natural area under a 1920 agreement with the Water and Power Resource Service (Bureau of Reclamation), which owns approximately five sections within the natural area.

The historical range of the desert pupfish extended over a broader area than at present. Except for San Felipe Creek, all original spring habitats have been lost. The population in the Salton Sea possibly originated from inundation of springs in the Salton Sink by the rising of the Salton Sea, or from populations present in the Colorado River at the time the Sea was formed. The Salton Sea and its agricultural drains, however, supply only marginal conditions for continued survival of the pupfish. The Sea itself has changed dramatically over the past 20 years, not only in salinity, but also in depth and species composition. The agricultural drains are poor pupfish habitat. The Imperial Irrigation District has plans for either filling, scraping, or concrete-lining these drains. During the quarterly surveys one complete drain (McKinley Street) was completely filled in between the summer survey and fall surveys. Obviously, the drains cannot be regarded as secure pupfish habitat.

The present work as well as several references describe various aspects of the physical habitat characteristics necessary for the desert pupfish (Moyle 1976, Soltz and Naiman 1978). The habitat characteristics generally favorable to desert pupfish include: (1) a sand-silt substrate; (2) an abundance of rooted aquatic plants and filamentous algae; (3) relatively shallow water (30 cm or less in depth); (4) a minimal surface flow (< 1.0 cfs); and (5) water temperatures above freezing during the winter.

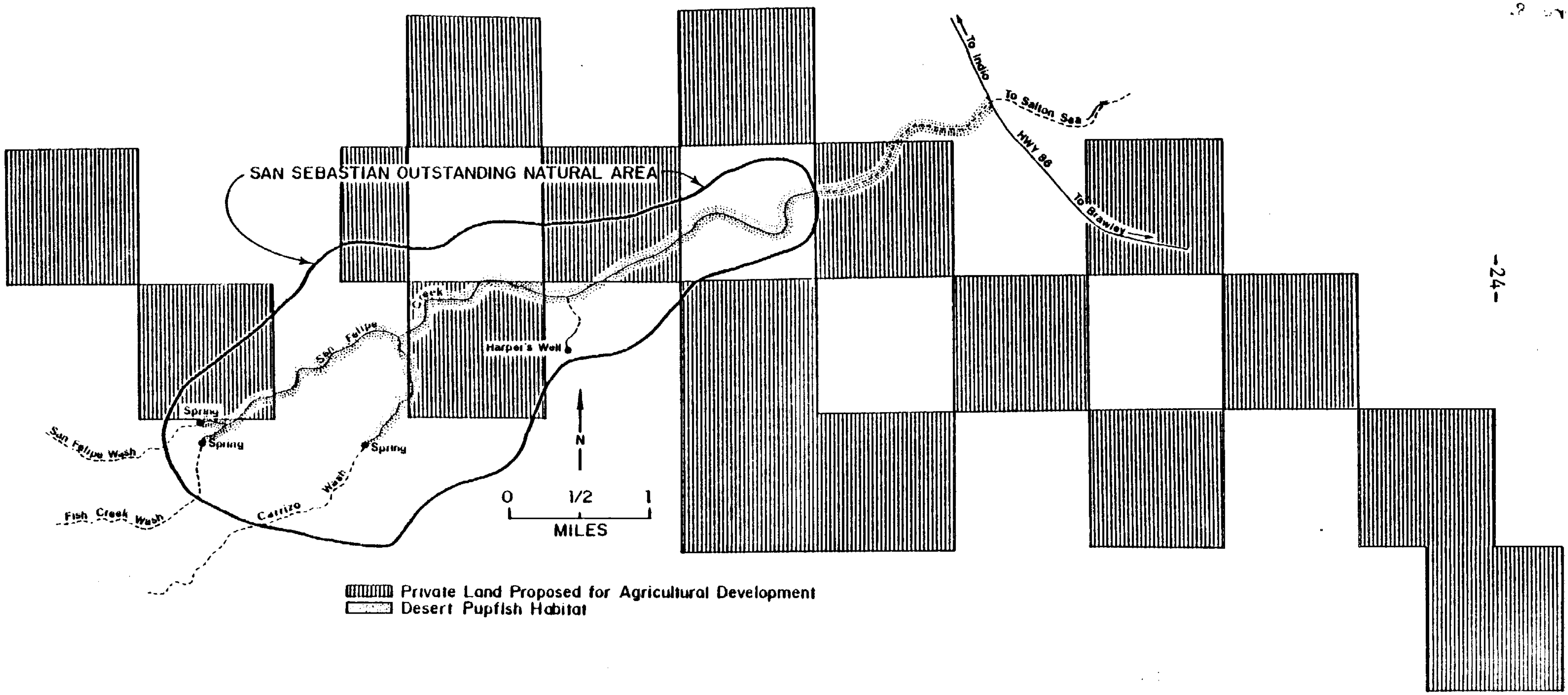


FIGURE 8. San Felipe Creek and San Sebastian Oustanding Natural Area, Imperial County, California.

An additional threat to the pupfish residing within the drains, sea proper, and permanent tributaries, is exposure to agricultural pesticides. There are sufficient examples of fish kills resulting from agricultural pesticide exposure in the Imperial Valley (Calif. Dep. Fish and Game, unpubl. records). Certainly any area providing refuge for the desert pupfish should have minimal pesticide use. One area which meets all of the above criteria and has an abundant pupfish population is San Felipe Creek, however, there are threats to this habitat also.

Lower San Felipe Creek and the lands bordering it have been zoned as open space in the Imperial County General Plan of 1973. This designation allows land to be developed for agriculture, which includes crop and tree farming and livestock, without any permit. In another part of the plan a stated goal and objective is "to preserve unique plant and wildlife by identification and preservation of natural habitats." Under a section called selected critical habitats, the plan says, "the following list of rare and endangered wildlife includes species not designated as rare or endangered according to the U. S. Department of the Interior, but whose habitats are threatened. It is planned that by timely and effective preservation measures these species will not become so classified: Fish - Desert Pupfish - San Felipe Creek Area." Another portion of the plan says, "Recommendation: Notify any agency responsible for protecting plant and wildlife before approving a project which would impact on rare or unique plant or wildlife habitat."

Recently two actions have been taken which could threaten the continued integrity of this area: First, the approval by the Imperial County Board of Supervisors of a proposal to subdivide a section of land adjacent to San Felipe Creek (Sec. 21, T. 12 S., R. 11 E.) for housing. The second action is agricultural development with associated ground water pumping of 17 sections (Sec. 13, 15, 19, 23, 25, 27, 29, 36, and east 1/2 section of 21 - T. 12 S., R. 10 E.; Sec. 19, 21, 27, 29, 31, 33, 35 - T. 12 S., R. 11 E.; and Sec. 1 - T. 13 S., R. 11 E.) of land immediately adjacent to San Felipe Creek. This second action is in compliance with the Imperial County General Plan, but both of these actions are incompatible with the previously stated concerns of the County for the preservation of San Felipe Creek and the desert pupfish. Currently there is little hydrological background data to predict the potential impact of irrigating these sections of land from ground water sources adjacent to the Creek. However, it is known from similar experiences elsewhere that ground water pumping could have a detrimental effect on surface water levels within San Felipe Creek and ultimately impact the desert pupfish.

STATUS

Desert pupfish no longer occur within their known historic range along the Colorado River and within numerous springs in the Salton Sink area. Pupfish presently occur, however, in three habitat types: (1) artificial refugia; (2) marginal habitats in and around the Salton Sea; and (3) a natural desert spring habitat in the San Felipe Creek drainage.

Desert pupfish have become established in all five temporary refugia into which they have been introduced. It is estimated that pupfish number approximately 1,000 individuals at Palm Canyon refugium, 100 fish at Living Desert Reserve, 30 individuals at Arrowweed Spring, 200 fish at Palm Spring refugium, and

200 individuals at the Visitor Center refugium. These refugium populations will help insure the continued existence of the desert pupfish, but like populations of other endangered species in zoos and similar artificial environments, they contribute nothing to the wild gene pool which must continue to respond to natural selective forces if the species is to persist as a viable component of a natural ecosystem.

As this report shows, the abundance of desert pupfish at various locations in and around the Salton Sea is relatively low and probably greatly reduced from historical times. The introduced exotic fish species probably have adversely affected once abundant pupfish through competition, predation, and behavioral interference. The limited populations around the Salton Sea appear to be occupying habitat marginally suited for pupfish. The agricultural drains support the largest number of pupfish within the Salton Sea system, however, current maintenance operations by the irrigation districts could further reduce or eliminate pupfish from these drains.

The historic distribution of the desert pupfish in their native habitat has been reduced to only San Felipe Creek. However, this habitat is presently threatened by residential and agricultural development on contiguous land. There is also a limited number of exotic fish species occurring in this same area of San Felipe Creek. This one prime pupfish area should be protected from further habitat loss or damage as well as further invasion by exotic fish species.

The available information strongly supports that the desert pupfish qualifies as an endangered species. The survival of the desert pupfish in California is in immediate jeopardy due to loss of a significant portion of its original habitat; the present or threatened destruction or modification of its existing habitat; and predation, competition, and behavioral interference by introduced exotic species.

RECOMMENDATIONS

The following actions should be taken to prevent extirpation of the desert pupfish from its limited natural range:

1. List the desert pupfish as an endangered species by both the State and Federal government.

2. Conduct hydrologic studies to determine the location of the ground water source/sources supplying permanent water portions of San Felipe Creek and determine the effects of ground water pumping on the surface flow in the Creek.

3. Request the Imperial County Board of Supervisors to zone land in and adjacent to San Felipe Creek in a category which excludes any type of development, which could be detrimental to the integrity of the habitat.

4. Request WPRS and/or BLM to acquire the remaining portions of private land in and adjacent to San Felipe Creek.

5. Investigate the feasibility of installing and maintaining a concrete spillway or drop east of State Highway 86, downstream from the permanent water, to prevent the upstream movement of exotic species during periods of flood.

6. Eradicate exotic fish species within the permanent water sections of San Felipe Creek.

7. Conduct biannual surveys of all known habitats to monitor any change in population abundance and distribution.

8. Obtain biological data necessary to effectively manage the species.

9. Establish a minimum of six refugia in areas far enough removed from one another geographically such that some catastrophic event would not exterminate all the refugia populations.

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APPENDIX 1. Numbers of Each Species Captured and Depth of Capture in Irrigation Drains at the Salton Sea During Four Desert Pupfish Surveys.

Drain	Length of drain (m)	Number of traps set	Species captured[1/]	Number captured S	Number captured S	Number captured F	Number captured W	Depth of capture (cm) S	Depth of capture (cm) S	Depth of capture (cm) F	Depth of capture (cm) W
Arthur	78	4	SLF		412	260	24		38-79	23-38	61-81
			SLF-SHF	208				61-91			
			DSP		1	2	1		71	23-33	61
			AFC			5	61			33-38	61-84
			LJM	12	11	3	2	61-91	38-79	33-38	84
Ave. 73	900	5	SLF		169	195	268		18-38	20-30	18-43
			SHF				1				18
			SLF-SHF	44				15-30			
			AFC	2	6	3	6	15-20	18-38	20-30	18-43
			DSP	1				15-20			
			CRF	38	23	15	3	15-46	18-38	20-30	18-36
			RS	28		3	4	15-46		30	18-46
Ave. 76		3	SLF		72	1	27		23-88	20	18-46
			SLF-SHF	93				30-46			
			AFC	3				30-46			
			DSP	2	1			30	23		
			LJM	2	5			46	38		
			RS		19	1			23-38	20	
			CRF		3		1		23		38
			MSQF				1				18
Barth	100	3	SLF		11	9	13		41	15	48
			SLF-SHF	37				15-20			
			DSP			1	6			33	48
			AFC			16				23-33	
			CRF	1		15		15-20		15-33	
			LJM			3				15	
			RS				3				48
Garfield Half	146	2	SLF		464	115			46-81	8-20	
			SLF-SHF	50							
			AFC			38	1			20	64
			LJM			2	4			20	64
			GC			1				8	

APPENDIX 1 (Contd)

Drain	Length of drain (m)	Number of traps set	Species captured[1/]	Number captured S	S	F	W	Depth of capture (cm) S	S	F	W
Grant	250	4	SLF		682	132	70		25-38	25-51	25-46
			SLF-SHF	5				30			
			AFC		2	7	7		30	25-51	25-46
			DSP			1				38	
			LJM			2				28-38	
Hayes	162	4	SLF		237	86	50		30-36	13-61	53
			SLF-SHF	1				30			
			AFC		2	1	2		30	61	53
			DSP			2				13	
			LJM		4		3		30-36		53
Johnson	4,000	10	SLF		515	74	86		20-41	13-46	23-56
			SHF		19		19		23		23-50
			SLF-SHF	27				30-46			
			PH		15	1			23-41	26	
			RS	112	27	1	6	30-46	23-48	13	28
			AFC	1	20	13	17	30	25-30	18-30	23-56
			LJM	1				61			
Niland 1	800	2	SLF		15	161			15	18	
			DSP	3	9			10-15	15		
			MSQF			12				18	
			CRF		2				15		
Niland 5	750	3	SLF	6		118		30		18-23	
			DSP	1			1	30			
			CRF	5				25-30			23
			MSQF	3		2		30		30-46	
			TFS		2				30-41		
			BG				1				43
			AFC			36				18-23	
"S"	200	3	SLF		1	2	3		18	15-48	107
			DSP		1				18		
			AFC		1				20		
			RS	1				61			
			LJM	1				61			
			TFS			1				15	
			CRF				1				23

APPENDIX 1 (Contd)

Drain	Length of drain (m)	Number of traps set	Species captured[1/]	Number captured S	S	F	W	Depth of capture (cm) S	S	F	W
Trifolium 7-A	105	4	SLF	2	53	29	119	30	18-25	13-18	30-17
			SHF	2				30			
			DSP	1				30			
			LJM	2				30			
			CRF	6	60	20	1	30	18-30	13-18	30
			AFC		2				18		
"U"	175	3	SLF	1	26	44	18	20	20-25	33	28-30
			DSP		8				20-25		
			AFC		10				23-25		
			LJM	1	3			46	23-25		
			CRF	9	3			15-20	23-25		
			MSQF		1		1		23		30
			YBH			2				33	
Unnamed	76	4	SLF		289	49	35		23-71	30-76	79-107
			SLF-SHF	209				30-61			
			DSP	1				30			
			AFC	1	11	12	49	30	30-71	30-76	79-107
			LJM	25	8		1	30-61	23-71		91
Vail 3-A	55	2	SLF	50	73	23	3	61	23-30	23-48	38-46
			DSP		67	29	74		30	23-48	38-46
			AFC	10	42			61	23		
Vail 4-A	85	2	AFC		23	1			61	51	
			CRF	3	4		10	30	61		41-51
Wheeler	140	4	SLF		941	237	74	30	33-61	23-30	18
			SLF-SHF	1							
			DSP		2	3			33-61	28-30	
			LJM		1		4		56		41-71
			AFC			1	1			30	

APPENDIX 1 (Contd)

Drain	Length of drain (m)	Number of traps set	Species captured[1/]	Number captured				Depth of capture (cm)			
				S	S	F	W	S	S	F	W
"Z"	3,000	4	SLF	3	35	25	5	15-20	10-46	10-18	20
			DSP		2				10-15		
			CRF	5	4			61	10		
			CP			2				10-13	
			RS				1				36

[1/] SLF = sailfin molly
SHF = shortfin molly
DSP = desert pupfish
AFC = African cichlid
LJM = longjaw mudsucker
RS = red shiner
PH = porthole fish
MSQF = mosquitofish
CP = carp
GC = Gulf croaker
BG = bluegill
YBH = yellow bullhead

APPENDIX 2. Dissolved Oxygen, Turbidity, and Temperature at Selected Areas During the Summer (S), Fall (F), and Winter (W) Surveys.1/

Area	Dissolved oxygen (ppm) S	Dissolved oxygen (ppm) F	Dissolved oxygen (ppm) W	Turbidity (JTU)2/ S	Turbidity (JTU)2/ F	Turbidity (JTU)2/ W	Salinity (ppm) S	Salinity (ppm) F	Temperature (°C) S	Temperature (°C) F	Temperature (°C) W
Arthur											
Source	3.6	5.0	5.2	2	10	0	9,100	10,500	26.5	28.0	21.0
Mouth	2.0	6.5	5.6	0	20	0	9,100	5,000	24.6	28.5	20.5
Barth											
Source		7.0	10.6		80	0		5,500		32.0	16.0
Mouth		6.5	10.0		70	0		7,700		32.5	17.0
Garfield Half											
Source	1.3	4.0	9.2	10	25	10	21,400	20,800	29.5	29.0	17.0
Mouth	1.0	6.5	8.3	10	10	10	24,200	26,100	29.5	31.5	16.5
Grant											
Source	5.8	3.0		8	0		5,000	10,000		25.5	
Mouth	2.1	4.5		20	15		12,300	14,600		26.5	
Hayes											
Source	2.2	5.0	7.2	10	5	0	16,000	2,100		27.0	18.0
Mouth	1.8	5.0	7.6	8	10	5	15,500	2,800		29.5	18.5
Johnson											
Source	4.6	5.5	6.8	2	5	20	18,200	6,800		26.0	19.0
Mouth	6.0	3.0	7.8	10	50	40	17,800	8,200		26.5	14.0
Niland 1											
Source		5.0	6.5	0	30	110	13,700	1,800		36.0	17.5
Mouth		3.0		45	25		22,800	3,600		30.5	18.0
Niland 5											
Source		7.0	10.2	>500	260	90	4,600	9,100		36.5	13.0
Mouth		6.5		>500	200		11,400	2,700		28.5	14.0
"S"											
Source		4.5	9.5		35	10		1,600		30.0	16.0
Mouth	1.7	6.5	9.4	420	90	5	3,600	1,400	28.0	32.0	16.0

APPENDIX 2 (Contd)

Area	Dissolved oxygen (ppm)			Turbidity (JTU)2/			Salinity (ppm)		Temperature (°C)		
	S	F	W	S	F	W	S	F	S	F	W
Trifolium 7-A											
Source	6.1	5.0	11.4	120	70	0	9,100	1,900	26.0	31.5	17.0
Mouth	6.1	6.0	9.8	112	90	10	7,800	2,000	27.0	30.5	15.0
"U"											
Source	2.2	6.0	10.6	0	30	30	3,600	13,600	27.0	27.0	11.0
Mouth	1.7	8.5	7.9	95	50	25	5,400	15,500	27.5	31.0	14.0
Unnamed											
Source	3.0	4.0	6.6	5	5	5	5,500	16,400	28.0	26.5	21.5
Mouth	2.4	4.5	5.8	8	15	5	17,800	10,000	27.5	26.0	18.5
Vail 3-A											
Source	4.8	4.5		112	10		11,000	19,600	36.0	28.0	
Mouth	5.3			65			6,200		27.0		
Vail 4-A											
Source		3.5			50			3,600		26.5	
Mouth	4.6			28			5,500		35.0		
Wheeler											
Source	1.2	6.0		0	5		16,000	4,300	27.5	27.0	
Mouth	2.4	6.0		12	15		24,600	5,600	32.5	30.0	
"Z"											
Source		5.5		15	10		13,700	3,600		31.0	
Mouth		4.5		35	10		13,700	4,600		33.5	
Shoreline Pool at Salton Sea National Wildlife Refuge	2.7	2.0		35	65		16,400	<45,500	36.0	28.5	
Shoreline Pool North of Salt Creek	1.6	1.2		62	350		21,800	<45,500	27.0	35.0	

APPENDIX 2 (Contd)

Area	Dissolved oxygen (ppm)			Turbidity (JTU)2/			Salinity (ppm)		Temperature (°C)		
	S	F	W	S	F	W	S	F	S	F	W
Salt Creek Tributary	1.6	4.0	8.6	130	125	180	5,500	10,900	26.0	26.0	14.0
Whitewater River											
Dillon Road		3.5	7.3		65	30	3,200			33.0	20.0
Marsh		4.5	8.6		40	20	7,300			27.0	15.0

1/ Indicates sites at which desert pupfish were captured.

2/ Measured during summer and fall surveys only.

APPENDIX 3. Numbers of Each Species Captured and Depth of Capture in Two Shoreline Pools of the Salton Sea During Quarterly Desert Pupfish Surveys.

Shoreline pool	Number of traps set	Species captured[1/]	Number captured				Depth of capture (cm)			
			S	S	F	W	S	S	F	W
Salt Creek	6	SLF	256	356	657	1	30	15-61	15-43	24
		DSP	1	4	1		30	20-28	18	
		LJM	10	21	82	134	30	15-61	15-43	24-44
		AFC	1		6		30		38-41	
Salton Sea National Wildlife Refuge	2	SLF	37	35	200	1	25-61	25-38	33-51	58
		SHF				1				58
		DSP	38	7	8	35	25-61	25-38	33-51	51-58
		AFC		17				25-38		

1/ SLF = sailfin molly
SHF = shortfin molly
DSP = desert pupfish
LJM = longjaw mudsucker
AFC = African cichlid

APPENDIX 4. Numbers of Each Species Captured and Depth of Capture in Three Tributaries to the Salton Sea During Quarterly Desert Pupfish Surveys.

Shoreline pool	Number of traps set	Species captured[1/]	Number captured				Depth of capture (cm)			
			S	S	F	W	S	S	F	W
Salt Creek	6	SLF	23	305	73		20-30	18-61	13-46	
		LJM	20	36	17	3	20-30	18-61	13-18	18
		DSP		3				46-61		
		CRF	1				20-30			
		AFC	2	4	7		20	20	18-46	
		GC			2				46	
Whitefield Creek	3	SLF	94	558	156	83	61	20-38	15-38	18-38
		SHF		18	42	27		20-38	15-38	18-38
		DSP			2				20	
		AFC		14	2	5		23-38	20	29
		LJM		13	6	15		23-38	15-20	29-38
Whitewater River	7	SLF	41	3	41	1	61-61	15	15-38	15
		SHF				1				15
		AFC	2	119	45	1	61	15-46	41	30
		RS		175	1	2		15-46	41	64
		CP			1				28	
		MSQF			1				28	
		LJM	1				61			

1/ SLF = sailfin molly
SHF = shortfin molly
DSP = desert pupfish
AFC = African cichlid
LJM = longjaw mudsucker
CRF = crayfish
GC = Gulf croaker
RS = red shiner
CP = carp
MSQF = mosquitofish

APPENDIX 5. Numbers of Each Species Captured and Depth of Capture in 13 Areas of the Salton Sea Proper During Quarterly Desert Pupfish Surveys.

Area	Number of traps set	Species captured[1/]	Number captured S	Number captured S	Number captured F	Number captured W	Depth of capture (cm) S	Depth of capture (cm) S	Depth of capture (cm) F	Depth of capture (cm) W
Mouth of Arthur Drain	1	SLF	1	9	45		46	48	53	
Sandbar between Arthur and Garfield Half Drains	1	SLF		390	1			48	56	
Mouth of Cleveland Drain	2	SLF		24	45			41	53-66	
Mouth of Colfax Drain	2	SLF		129	79			41-66	36-69	
		AFC		2	1			41	36	
		LJM				5				43-64
Sandbar between Colfax and Grant Drains	1	SLF		115	41			50	38	
		LJM				3				43
Mouth of Garfield Drain	1	SLF		233	62			50	30	
		LJM		1				50		
		ORC		3				50		
Mouth of Garfield Half Drain	2	SLF		25	20			91	30	
		AFC		2				91		
		ORC		1				91		
Mouth of Grant Drain	2	SLF		378	156	1		56-58	64	91
Mouth of Hayes Drain	2	SLF		7	27	2		36	36-56	41
		GC							56	
		DSP				1				41
		LJM				1				58
Mouth of McKinley Drain	1	SLF		1	96			48	51	
		ORC		14				48		
		AFC			1				51	
		LJM				2				48

APPENDIX 5 (Contd)

Area	Number of traps set	Species captured[1/]	Number captured S	Number captured S	Number captured F	Number captured W	Depth of capture (cm) S	Depth of capture (cm) S	Depth of capture (cm) F	Depth of capture (cm) W
Barnacle bar off North Shore Airport	2	SLF	22	2	199	2	30-46	48	36-48	38
		ORC		6	1			48	48	
Mouth of Unnamed Drain	1	SLF			67				41	
		GC			1				41	
		LJM				1				58
Mouth of Wheeler Drain	1	SLF	1	43	2		30	36	86	
		AFC		1				36		

1/ AFC = African cichlid
DSP = desert pupfish
GC = Gulf croaker
LJM = longjaw mudsucker
ORC = orangemouth corvina
SLF = sailfin molly

APPENDIX 6. Numbers of Each Species Captured and Depth of Capture in Two Surveys of San Felipe Creek.

Survey	Number of traps set	Species captured[1/]	Number captured	Depth of capture (cm)
Fall	18	DSP	267	25-152
		SLF	109	15-152
		MSQF	14	38-53
		SHF	5	35-55
Winter	8	DSP	26	14-44

1/ DSP = desert pupfish
SLF = sailfin molly
SHF = shortfin molly
MSQF = mosquitofish