Bull. Southern California Acad. Sci.
78(1), 1979, pp. 46–55

Niche Separation Within a Population of Freshwater Fishes in an Irrigation Drain Near the Salton Sea, California

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Abstract.—The fish fauna of the King Street canal is a mixture of native and introduced species. Inflow from a thermal well at 42°C and irrigation runoff at 22°C were responsible for a thermal gradient that, in addition to differences in flow, held fishes in remarkably pure species populations. On 19 March 1977, *Cyprinodon macularius* was found most abundantly in water 10 cm deep at 39°C. *Gambusia affinis* occurred in flowing water 25 cm deep at 32°C. Only *Poecilia sphenops* inhabited a cool water outflow 18 cm deep at 22°C. Downflow, *Poecilia latipinna* was taken most commonly in slow moving water up to 50 cm deep at 26°C, and *Notropis lutrensis* occurred in riffles up to 25 cm deep at similar temperatures. Flooding during late summer 1977 and subsequent reconstruction of the canal obliterated most of the habitat diversity. All five species survived, albeit seriously reduced in number, and the species sorting that was previously observed also was no longer in evidence. Thermal differences remained, and a pond was constructed that impounded hot water. Later, on 17 July 1978, the pond included *Cyprinodon macularius, Gambusia affinis, Poecilia latipinna* and a new introduction, *Tilapia zilli*. Downstream, *Cyprinodon macularius, Poecilia sphenops,* and *Notropis lutrensis* were taken in flowing water.

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Introduction

An interesting assemblage of freshwater fishes inhabits waterways and canals draining into the Salton Sea in Riverside and Imperial Counties, California (Table 1). Most of these drains carry irrigation runoff, and represent permanent aquatic habitats. The fish fauna of these waterways is a mixture of aquarium species, escaped bait fishes, introduced game fishes, introduced "weed eaters," and one native form, a subspecies of *Cyprinodon macularius*, the desert pupfish.

On the northwest side of the Salton Sea, in the King Street canal, a thermal outflow was responsible for marked diversity in habitats not apparent in other drains (canals). In most of these canals fish species are found in mixed assemblages. Fish distributions in the King Street canal seemed to reveal preferences for distinct habitats, each occurring in virtually pure species populations. Flooding and subsequent reconstruction of the canal appeared to obliterate the distinct habitats and thus provided an opportunity to study the influence of habitat diversity on fish distribution.

This study documents nearly complete niche separation among introduced freshwater fishes in an "unnatural habitat," illustrating rapid selective forces in action, and it describes the effect of habitat alteration on niche stability. The study also describes habitat and potential threats to the desert pupfish, *Cyprinodon macularius*, the only native fish in the area.

Table 1. Fishes known to inhabit irrigation canals and waterways in the vicinity of the Salton Riverside and Imperial Counties, California.

Species	Reference
Dorosomidae	
Dorosoma petenense	Black, pers. comm.
Cyprinidae	
Carassius auratus	Personal observation
Cyprinus carpio	Mearns, 1975
Notropis lutrensis	Personal observation
Notemigonus chrysoleucus	Soltz, pers. comm.
Cyprinodontidae	
Cyprinodon macularius	Personal observation
Poeciliidae	
Gambusia affinis	Personal observation
Poecilia latipinna	Personal observation
Poecilia mexicana	Personal observation
Poecilia sphenops	Personal observation
Poeciliopsis gracilis	Mearns, 1975
Xiphophorus helleri	Mearns, 1975
Xiphophorus variatus	St. Amant and Sharp, 1971
Centrarchidae	
Micropterus salmoides	Soltz, pers. comm.
Lepomis cyanellus	Personal observation
Ictaluridae	
Ictalurus [illegible]bulosus	Personal observation
Ictalurus punctatus	Soltz, pers. comm.
Sciaenidae	
Bairdiella icistia	Soltz, pers. comm.
Cynoscion nobilis	Personal observation
Cichlidae	
Tilapia mossambica	St. Amant, pers. comm.
Tilapia zilli	Personal observation
Gobiidae	
Gillichthyes mirabilis	Personal observation

Materials and Methods

The canal that parallels King Street lies 7 km north of the Riverside Impe County line on the northwest side of the Salton Sea. Observations and collecti of fishes were made on 3 March 1977, 21 May 1977, 18 March 1978, and 17 . 1978. The area provided a unique opportunity to study factors that influence distribution because depth varied only slightly (5 to 50 cm) and there was pre a striking thermal gradient in addition to variations in turbulence and veloc Flow was generally shallow and linear. Riffles alternated with laminar flow undercut banks were present in association with meanders. A hot artesian flowed into the canal. At its source the water was 46°C. Approximately 5 downflow where the water cooled to 39°C fishes began to appear. From that p

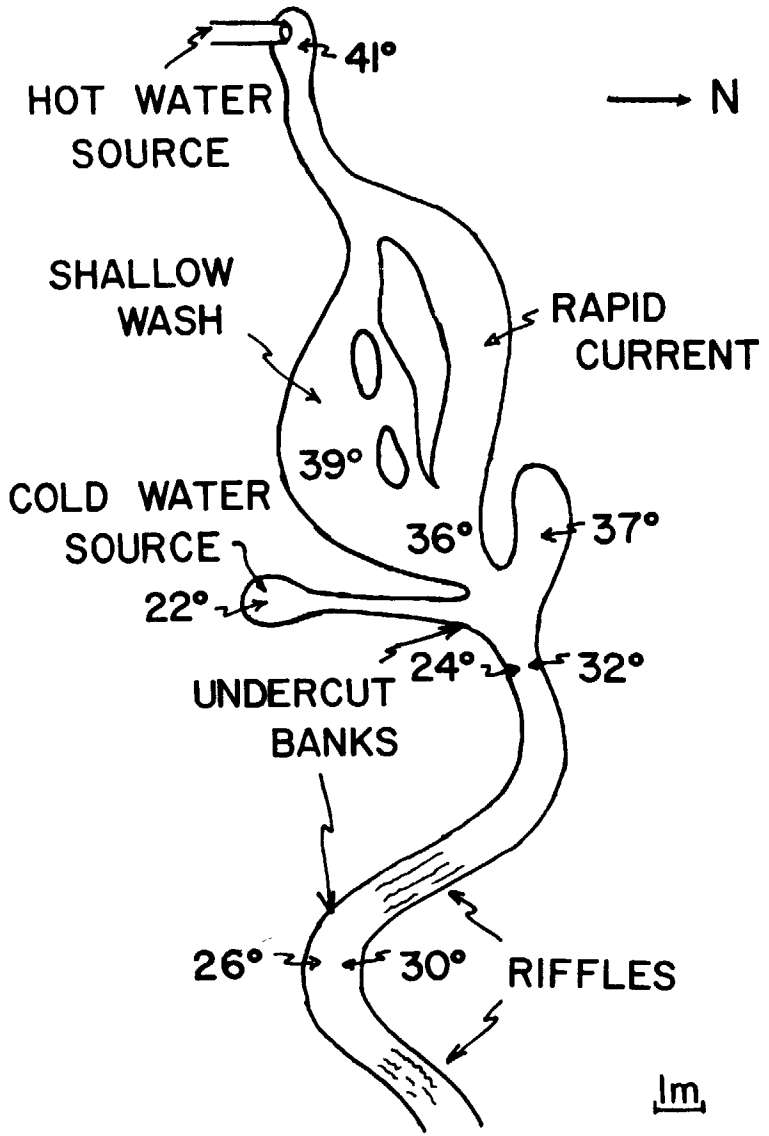

Fig. 1. Diagram of upper portion of King Street canal indicating differences in stream flow and temperature (3 March 1977). Fishes occur in nearly pure species groups as follows: *Cyprinodon macularius*, shallow wash; *Gambusia affinis*, flowing water at 32°C; *Poecilia sphenops*, cold water source; *Poecilia latipinna*, undercut banks; and *Notropis lutrensis*, riffles. Temperatures in °C.

to the mouth of the canal fishes were collected using a 1 m nylon seine with *ca.* 3 mm bar measure. Some specimens of each species were preserved in 10% formalin to insure correct identification. In order not to damage living fishes, counts of individuals were not made, and most fishes were released at their collection sites after identification. Temperatures at each collection site were

Table 2. Habitat preferences for fishes inhabiting the King Street canal, Riverside County, fornia on 3 March 1977

Species	Water Temp. (°C)	Diss. O_2 (mg/l)	Depth (cm)	Flow	Physical habitat
Cyprinodon macularius	39	6.8	5–10	slow	shallow wash
Gambusia affinis	32	7.0	25	moderate	stream margin
Poecilia sphenops	22	8.5	18	rapid	stream source
Poecilia latipinna	26	8.5	50	slow	undercut banks
Notropis lutrensis	26	8.7	8–15	rapid	riffles

Analyzer, and other chemical aspects of water quality were determined usin Bausch and Lomb Minispec 20 spectrophotometer.

Results

On 3 March 1977 collections of fishes revealed nearly complete species s aration along various parts of the canal (Fig. 1, Table 2). Only desert pupfi *Cyprinodon macularius*, were found in the shallowest, hottest water. They w abundant in water up to 10 cm deep at 39°C. An adjacent area of faster mov water at 32°C and 25 cm deep was inhabited only by schools of mosquitofi *Gambusia affinis*. A few meters downflow, cold water at 22°C bubbled fron submerged pipe. At that point a small pool, 18 cm deep, contained in abunda only one species of fish. These were mollies of the "shortfin" group that h been identified by their dentition in accordance with Hubbs (1961) as *Poeci sphenops*, although in coloration they resemble a variety of *Poecilia mexica* known in the aquarium trade as "liberty mollies" (Miller, pers. comm.). Mat males and females of this variety have a distinctive orange band in the dorsal and carry no striking colors on the caudal fin. In the Johnson Street canal on eastern side of the Salton Sea "typical" *Poecilia mexicana* have a metallic b caudal fin with a distal orange band. These mollies are found in a similar habi along with the porthole fish, *Poeciliopsis gracilis*. The assemblage in the Johns Street canal has been described by Mearns (1975).

Water mixed slowly as it flowed in the King Street canal, the southern half the stream remaining noticeably cooler for approximately 100 m. Water in t channel varied from 1 to 4 m in width and never was more than 50 cm deep. meandered numerous times. Slow moving water up to 50 cm associated w undercut banks alternated with broad, fast moving riffles *ca.* 8 to 15 cm de Temperature varied from 24° to 27°C. Sailfin mollies, *Poecilia latipinna*, inhabi slow moving portions of the run, and red shiners, *Notropis lutrensis* were fou in the riffles. Species overlapped very little in these habitats, although so *Poecilia sphenops* occurred in faster moving water with *Notropis* in upper p tions of the run where the water temperature was 27°C. Approximately 2 downflow the stream broadened to a floodplain no more than 10 cm deep and to 5 m wide. *Cyprinodon* abounded in this area among roots of cattails (*Typh* and rushes (*Juncus*).

On 21 May 1977 the area was revisited. Distribution of fish species had chan

Fig. 2. View east of upper portion of King Street canal (3 March 1977). Cold water source to extreme right center and undercut bank to left of center. Shallow wash to lower right.

The thermal water measured *ca.* 2° cooler. The cold source was the same. Dissolved oxygen measurements ranged from 7.2 mg/l at 37°C to 8.5 mg/l at 22°C. Other measures of water quality such as total dissolved solids at 1.1‰ showed little variability between the stations.

On 18 March 1978, one year later, the area was visited in order to assess the influence of flooding on the previously observed niche separations. Heavy rains occurred during late summer 1977 and winter 1978. The area barely was recognizable. Discussion with nearby residents revealed that flooding had obliterated the stream banks, allowing water to flow over 3 m deep and 15 m wide. Virtually all rooted vegetation was removed. The following February, the channel was rebuilt. Bulldozers reconstructed canal walls, the bottom was scraped, and portions were stabilized with rocks held in place by wire mesh and iron posts. Figures 2 and 3 depict the canal before and after reconstruction.

Reconstruction greatly reduced habitat diversity and sorting of fish species was poorly defined (Table 3). The hot water and cold water inflow pipes were in their former positions and a temperature gradient remained. Above the cold water inflow a small earthen dam had been constructed, apparently to impound the hot water. This impoundment was a full meter in depth at the center and apparently

Fig. 3. View east of King Street canal following reconstruction (18 March 1978).

Water temperature in the upper 3 cm was 36°C and dissolved oxygen was 7 mg/l. At the upper, shallow end of the pond numerous young *Cyprinodon* wer collected and released. A small number of *Poecilia latipinna* and *Gambusia a finis* also were collected in this shallow area although they were more comm in deeper portions of the pond.

Downstream *ca.* 2 km the water course broadened as before, although distin high banks had been constructed. No fishes were collected here, and there w no rooted vegetation. At the mouth of the channel, where it opened into t Salton Sea, *Poecilia latipinna* was abundant. It also abounded along the edge the Salton Sea, in areas where the substrate was an odoriferous, black organ ooze.

On 17 July 1978 another visit to the canal revealed that a portion of the da that impounded the water had broken down and the pond was only 60 cm dee No collections were made, but visual observations were enhanced by very cle water. Apparently *Tilapia zilli* had been introduced since the last visit. Two adul were observed swimming in the pond. The surface temperature was 40°C. In shaded shallow of approximately one square meter surface, in water 32°C and n deeper than 3 cm, were swarming a mixture of *Cyprinodon macularius*, *Poecili latipinna*, *Gambusia affinis*, and juvenile *Tilapia zilli*. Backs of the fishes fr quently protruded from the water giving the area the appearance of boiling.

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Table 3. Habitat preferences for fishes inhabiting the King Street canal, Riverside County, California on 18 March 1978.

Species	Water Temp. (°C)	Diss. O_2 (mg/l)	Depth (cm)	Flow	Physical habitat
Cyprinodon macularius	36	7.2	2–100	slow	pond margin
	27	8.3	10	rapid	riffles
Gambusia affinis	36	7.2	2–100	slow	pond center
Poecilia latipinna	36	7.2	2–100	slow	pond center
	28	7.8	50	slow	stream margin
Poecilia sphenops	27	8.3	10	rapid	riffles
Notropis lutrensis	26	8.3	10	rapid	riffles

the preferences exhibited by the population in the King Street canal. Some differences, however, are worth noting.

In the Garfield Street canal *Cyprinodon macularius* were collected as recently as 7 December 1975 in water 50 cm deep among roots of cattails. That area is now inhabited by *Tilapia zilli* which were introduced to the Salton Sea area in 1971 for the purpose of weed eradication (St. Amant, pers. comm.). *Tilapia* are aggressive, feeding on detritus as well as aquatic vegetation. They probably also eat fish eggs. My collections seem to indicate that where pupfish formerly abounded, *Tilapia* are now common. *Tilapia* apparently were not present in the King Street drain until recently. Observations of relative abundance of the two species will be continued to determine if *Tilapia* appears to replace *Cyprinodon*.

Desert pupfish formerly were abundant in shoreline pools at the edge of the Salton Sea (Barlow, 1958a, b; Walker et al., 1961), and even were able to dive into the reducing, malodorous mud without apparent harm (Lowe et al., 1967). During rainy months certain pools along the north shore still are inhabited by pupfish (Black, pers. comm.), but such habitat adjacent to the mouth of the King Street canal seemed to be inhabited solely by swarms of sailfin mollies. It likewise seemed true near the mouth of the Avenue 81 canal where seine hauls yielded only *Poecilia latipinna*. Perhaps something about newly inundated land is hostile to desert pupfish. The Salton Sea is rising rapidly. Surface level has risen *ca.* 60 cm since September 1975 (Skjold, pers. comm.). Perhaps nesting is upset when the water level rises too rapidly. Perhaps there is too much organic material in the substrate or water. Perhaps peculiar combinations or lethal concentrations of mineral ions are responsible. Whatever the case, it appears that the natural range of *Cyprinodon macularius* in the area has shifted such that freshwater drains and water courses leading to the Salton Sea are now the primary habitat.

Discussion and Conclusions

The sorts of preferences indicated by this study are notable in view of the wide range of tolerances exhibited by these fish species. The hottest water inhabited by fishes in the King Street canal, 40°C, is either within, or not far above the known upper limit of these species as follows: *Notropis lutrensis*, 39.5°C (Brues, 1928); *Poecilia sphenops*, 35.6°C (Miller, 1949); *Gambusia affinis*, 39.5°C (Hubbs,

1959); and *Cyprinodon macularius*, 44.6°C (Barlow, 1958a, b; Lowe a 1969). *Poecilia latipinna* was recorded in the pond at 36°C and *Tila* 40°C. Of course, temperature stratification occurs and fishes may not r occur at the temperature where the reading was taken. Nevertheless, eral species occur together, and the habitat is suitably diverse it is n they disperse themselves according to definable preferences.

Temperature tolerances notwithstanding, the oxygen supply of natu is probably the most frequent single factor influencing the life of de (Deacon and Minckley, 1975). In the King Street canal, however, a flowing and approaches saturation for dissolved oxygen. Prior to cons the pond, depth varied only slightly, ranging from 5 to 50 cm, therefo ature and physical characteristics such as turbulence and velocity are the significant parameters responsible for the observed sorting of spe paring the King Street canal to other canals in the area, it leads conclusion that temperature is a very important factor. The pronounc gradient, from 46°C to 22°C superimposed upon differences in flow differences in depth was responsible for a nearly pure sorting of specie habitat preferences. Considering that all but one of the species is int further indicates that selective forces act rapidly.

The native pupfish, *Cyprinodon macularius*, formerly inhabited sloughs, and backwaters of the Colorado, Gila, and Sonoyta Rivers (I Miller, 1941; Miller, 1961). That habitat in the Salton Sea area is m approximated by warm, shallow, slow moving waters, particularly in with rooted aquatic vegetation or algal mats. Desert pupfishes also inh pools along the edge of the Salton Sea, at least during the rainy season habitats now seem mainly to contain sailfin mollies, perhaps due t conditions associated with the rapidly rising water, *ca.* 60 cm since S 1975. In the King Street canal *Cyprinodon* was most abundant in a sh at 39°C. It also was common *ca.* 2 km downflow in shallow water an of cattails and sedges.

"Liberty mollies," identified on the basis of dentition as *Poecilia* appeared to inhabit only the King Street canal, and were found most near the outflow of water at 22°C. In some of the other canals this occupied by the closely related shortfin molly, *Poecilia mexicana*, a *ciliopsis gracilis*, neither of which was collected in the King Street shiners, *Notropis lutrensis* were the only fishes collected in riffles o Street canal although they also were taken in small numbers with *Poe nops* in fast moving water other than riffles. By comparison, it is int note that my collections of *Notropis* from the Gila and Verde Rivers seemed to indicate that they preferred slow moving water deeper thar

The most common fishes of the canal system were sailfin mollies *latipinna*. In the King Street canal they preferred slow moving water ation with undercut banks. They reached their greatest abundance i water near the mouth of the canal, and in shallows at the edge of the where the substrate had become an odoriferous, black, anaerobic gel.

Mosquitofish, *Gambusia affinis*, occurred in slow moving waters at King Street canal. In other canals they were found in slow moving *latipinna*, bu

current as the mollies. Also, they seemed to avoid shallow or weedy areas inhabited by desert pupfishes.

The impact of flooding or other forms of habitat destruction on niche preferences is marked. In the Avenue 81 canal *Notropis lutrensis* used to be common along with *Poecilia latipinna*. Since the flooding of September 1976, however, it appears that *Notropis* may have been eliminated. After three pronounced floods, *Cyprinodon macularius*, the native species, and *Poecilia latipinna* occur there as before. Regarding *Poecilia latipinna*, it is interesting to note that it apparently was the only species extirpated from the Salt River near Mesa, Arizona by the flood of 1970 (Minckley, 1973). Apparently the ability of sailfin mollies and desert pupfish to tolerate saline waters of the Salton Sea enables them to reinhabit these canals after flooding. Perhaps the absence of such a refuge in the Salt River led to the demise of *Poecilia latipinna* in the Salt River.

In the King Street canal, flooding and subsequent reconstruction dramatically reduced the diversity of habitat and the striking examples of niche separation observed in 1977 were obliterated. All original species were still present as recently as 17 July 1978 and some examples of species sorting were still observable, but they were far less obvious. Essentially two habitats remained, cool flowing water and impounded hot water. The former was inhabited by *Notropis lutrensis*, *Poecilia sphenops*, and a few *Cyprinodon macularius*. The impounded hot water apparently is used for washing clothes and human bathing. Recently *Tilapia zilli* was introduced here. *Poecilia latipinna*, *Gambusia affinis*, and *Cyprinodon macularius* were found there with the *Tilapia*. The ability of this population of desert pupfishes to tolerate pollutants from human bathing and washing clothes as well as encroachment by *Tilapia zilli* remains to be seen.

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