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The Desert Pupfish of the Salton Sea: A Synthesis

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1.0 Introduction

The desert pupfish (Cyprinodontidae, *Cyprinodon macularius* (Baird and Girard 1853)) is the only fish endemic to the Salton Sink. There are two subspecies in the United States: a Colorado River form (*C. m. macularius* Baird and Girard) and a Quitobaquito form (*C. m. eremus* Miller and Fuiman) (Marsh and Sada 1993). This report focuses on *C. m. macularius*, whose wild populations occur around the Salton Sea (Marsh and Sada 1993). Information was obtained from a literature search conducted by the California Department of Fish and Game (CDFG), an internet search, and from the library at the Bureau of Reclamation in Denver, Colorado. Recent unpublished survey data were obtained from CDFG.

2.0 Distribution and Abundance in the Salton Sea

Desert pupfish were once widespread and abundant in portions of southern Arizona and southeastern California, United States, and northern Baja California and Sonora, Mexico (Miller 1943). In 1859, Girard first reported desert pupfish in California in some saline springs in Imperial County (Jordan, Evermann, and Clark 1930). After the Salton Sink was flooded in 1904-1907 by diversion of the Colorado River, desert pupfish colonized what is now known as the Salton Sea (Thompson and Bryant 1920) and was reported as "abundant" by several authors (Coleman 1929; Cowles 1934; Barlow 1958, 1961; Walker 1961). However, only Barlow (1961) provided an estimate of 10,000 individuals in a single shoreline pool of the Salton Sea. Collections made by CDFG and others, including Schoenherr (1979), in the late 1950s to early 1960s indicated that desert pupfish abundance at the Salton Sea was severely declining (Black 1980). In surveys conducted by CDFG in 1978-1979, desert pupfish accounted for 3 percent of the total catch in irrigation drains, 5 percent of the catch from shoreline pools, and less than 1 percent of the catch from three natural permanent tributaries and the Salton Sea proper (Black 1980). However, desert pupfish accounted for 70 percent of the total catch from San Felipe Creek, an intermittent tributary to the Salton Sea.

The desert pupfish was listed as a California endangered species in1980 (CDFG 1980). The U.S. Fish and Wildlife Service (FWS) listed this species and its critical habitat as endangered in 1986 because of habitat alteration, introductions of exotic species and contaminants, and other habitat impacts (FWS 1986). Designated critical habitat includes San Felipe Creek, Carrizo Wash, and Fish Creek Wash in Imperial County, California (FWS 1986). Figure 1 shows the general distribution of desert pupfish around the Salton Sea. Current desert pupfish populations occur in drains directly discharging to the Salton Sea, in shoreline pools of the Salton Sea, several artificial refugia, and in desert washes at San Felipe Creek and Salt Creek. Pupfish are not known to occur in the New or Alamo Rivers because of the high sediment loads, excessive velocities, and presence of predators (Imperial Irrigation District 1994).

Dunham and Minckley (1998) reported that recent declines in non-native fishes, presumably in response to increasing salinity, have been paralleled by a rebound of pupfish populations in the Salton Sea. However, surveys in the various habitats around the Salton Sea indicate a general decline in desert pupfish abundance and distribution since 1991 (Table 1). In 1991, 41 irrigation drains contained pupfish. In 1993, desert pupfish were trapped in 33 drains and in San Felipe Creek (Remington and Hess 1993). In this survey, 504 desert pupfish were trapped, compared to 161 in 1991. The difference was attributed to the larger number of traps placed in each drain in 1993 compared to 1991. Trifolium 12 Drain had the greatest number of desert pupfish (261) (Table 1). Only 11 irrigation drains contained pupfish in 1998, and the numbers of desert pupfish also declined from the earlier surveys.

Extreme annual variability in catch numbers has occurred at some individual sample sites (e.g., County Line Drain and Trifolium 12 Drain) (Table 1). Variability in catch also occurs within a season. Nicol, Lau, and Boehm (1991) found that some drains which did not yield pupfish during one trap set often produced pupfish in subsequent trappings. This suggests that desert pupfish may move among habitats for various reasons (e.g., avoiding predators, feeding, spawning). A variety of other factors may also influence trap results, including location of trap placement, numbers of traps, bait types, timing, water level fluctuations, and vegetation removal (Nicol, Lau, and Boehm 1991).

Table 1. Numbers of desert pupfish collected from various surveys at Salton Sea.

	YEAR						
DRAINS	**1991[1]**	1993[2]	1994[3,4]	**1995[4,5]**	**1996[4]**	1997[4,5]	1998[4]
NORTH END							
County Line	*				490	6	4
Oasis Grant	7						
Ave 84	38	27			*		1
Ave 83	5	1			27		1
Ave 82	*	4			*		1
Ave 81	3	5			6	6	8
Ave 80	80						
Ave 79	22	35	7				
Ave 78	155	84	1				
Ave 76	1	8	16		1		
Ave 74			1		3		
Ave 73			6				
Ave 68			2				
King Street	67		12		8	14	3
McKinley 0.5	*						

Table 1 (Continued)	1991	1993	1994	1995	1996	1997	1998
McKinley	17	51					
Cleveland 0.5	10	12					
Cleveland	18	29					
Arthur 0.5	18	6					
Arthur	4	8					
Garfield 0.5	2						
Garfield	*	1			1		
Hayes 0.5	9						
Hayes	2	79					
Grant 0.5	7						
Grant	92	5					
Johnson 0.5	37	17			1		
Lincoln		1					
Buchanon			*				
SOUTH END							
Niland 4	19						
Niland 3		1					
Niland 2	2						
Niland 1		1	2				
Z		1	3				
W		11	356				1
T			2				
S		4	1				1
R		2	1		1		
Q			10				
P			10				
O			1				
Vail 4A	1						
Vail 56	44		53				
Vail 5A	26						
Vail 6	1						
Vail cut-off		1	2				
Vail 7		4	3				
Trifolium 12		261	3		1		
Trifolium 13		38	1				1
Trifolium 14A			1				1
Trifolium 1	9		1		1		
Tri Storm	1	2	3		16		2

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Table 1 (Continued)	1991	1993	1994	1995	1996	1997	1998
Trifolium 18	2		2				
Poe	13	1	3		1		
Lone Tree Wash	8						
3W of Lone Tree	6						
Trifolium 19	8		3		1		
Trifolium 20		50	7				1
Trifolium 20A					13		
Trifolium 22		34	47				
Trifolium 23	13	64	22		1		
Trifolium 23N	2						
WP-10 SS-11	1						
S. Felipe Wash	5	3	1		31		
POOLS							
S. of Bombay	23						
N. of Niland 4	30						
N. of Niland 3	9						
N. of Niland 1	4						
"U" drain pool							1
W. of New River	7						
S. of New River	1						
E. of Tri 22	6						
By Tri 23	4						
By Tri 23N	*						
N. of Tri 20A							70
N. of Grant 0.5							2
N. of Hayes 0.5					2		
S. of Salt Creek				3			
TRIBUTARIES							
S. Felipe Creek	*	224	195	115	*	388	*
Upper Salt Creek		9	15	45	18	102	
Lower Salt Creek	1			12			

* - observed

[1] Nicol, Lau, and Boehm (1991).
[2] Remington and Hess (1993).
[3] Schoenherr (1994) - Only surveyed north end drains.
[4] CDFG, unpublished data.
[5] No drain surveys in 1995; only north end drains surveyed in 1997.
[6] Also considered a shoreline pool.

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3.0 Habitat Requirements and Life History

The desert pupfish is a small (<76 mm), laterally compressed "killifish." Pupfish typically prefer shallow, clear water, with either rooted or unattached aquatic plants, restricted surface flow, and sand-silt substrates (Black 1980; Marsh and Sada 1993). They can live in extreme environmental conditions: salinities ranging from nearly twice that of seawater (68 ppt) to that of freshwater; temperatures from 45°C in the summer to 9°C in the winter; and oxygen levels from saturation down to 0.1 to 0.4 ppm (FWS 1986). They can also survive 10 to 15 ppt changes in salinity as well as daily temperature fluctuations of 22° to 26°C (Kinne 1960; Lowe and Heath 1969). Thus, they are found mostly in habitats too extreme for other competing fishes. In less harsh environments where a greater diversity of fishes are found, pupfish occupy water shallower than that inhabited by adults of most other species (Marsh and Sada 1993). Smaller fish tend to be found in shallower water than larger fish.

Schoenherr (1990) observed the effects of a flash flood on the Salt Creek pupfish population. In 1990, 229 pupfish were collected during 2 surveys before the flash flood occurred on June 9, followed by 93 pupfish collected during 3 subsequent surveys. He found that large fish were washed out and small fish repopulated thereafter. Also, non-native fish were more common after the flood, apparently from being washed down from the upper parts of the drainage. No desert pupfish were captured in the 1998 surveys in upper and lower Salt Creek, which suggests that non-native fish and water releases/pond filling at Dos Palmas may be affecting the pupfish population (CDFG 1998).

In the Salton Sea, pupfish of all ages move in and out of shallow areas in shoreline pools during the day, apparently to avoid temperatures higher than 36°C (Barlow 1958). In the summer they move into deeper, warmer water in the morning and concentrate in shallow, warm water during the day until the water temperature rises above 36.5°C; then they move to deeper water until the shallows cool. They spend the nights in the shallowest, coolest areas of the pools. During the winter the pupfish do not move into the shallows until mid-afternoon, and they remain there into the night (Barlow 1958). Some populations of desert pupfish bury themselves in loose debris on the bottom and become dormant during the winter (Cox 1966). They may also avoid excessively high temperatures by burrowing (Moyle 1976).

Typically, desert pupfish swim in loose schools of similar age. They mature rapidly, with as many as three generations per year. Although pupfish can become sexually mature at 15 mm TL, most do not breed until their second summer when they reach 75 mm TL (Moyle 1976). Spawning at the Salton Sea occurs between late March through late September (Matsui 1981) when water temperatures exceed 20°C (Moyle 1976). During the breeding season, males become territorial and the schools consist either entirely of adult females or entirely of juveniles. Courtois and Hino (1979) showed that desert pupfish prefer 18 to 22 cm deep water for egg deposition. Territories are also centered on some small submerged object or bump on the bottom. Basic spawning behavior was observed in shoreline pools along the Salton Sea by Barlow (1961). The female, when ready to spawn, is attracted to a territorial male and leaves her school. She approaches the male who moves towards her and lies parallel to her. The two fish then bend together into an "S" and the male cups his anal fin around the vent of the female. The female trembles and lays a single egg, which is fertilized by the male. Several eggs may be deposited on the bottom in this manner, with each spawning act taking less than a minute. Depending on her size, a female may lay 50 to 800 eggs or more during a season (Crear and Haydock 1971). The eggs hatch in 10 days at 20°C, and the larvae start feeding on small invertebrates within a day after hatching (Crear and Haydock 1971). The larvae are frequently found in shallow water where environmental conditions can be severe.

Desert pupfish are omnivorous, feeding on whatever small invertebrates and algae are available to be picked off the substrate (Naiman 1979). In general, when invertebrates are available, they are the preferred food of foraging pupfish. In the Salton Sea, this means ostracods, copepods, and occasionally insects and pile worms (Moyle 1976). Walters and Legner (1980) found that pupfish foraged mostly on the bottom, consuming midge larvae, detritus, aquatic vegetation, and snails. They also found that in rice fields, pupfish forage on littoral Cladocera, Coleopterous larvae, and mosquitoes. As invertebrates become less available, pupfish adjust their feeding behavior and their gut usually contains large amounts of algae and detritus, as well as invertebrates; occasionally they will eat their own eggs and young (Cox 1972). Foraging is typically a daytime activity (Moyle 1976). They are not considered important food for piscivorous birds or fish because of sparse density (Walker et al. 1961; Barlow 1961).

Turner (1983) detected genetic differences among four Salton Sink populations, and a low level of inter-population differentiation. In contast, Dunham and Minckley (1998) and Echelle (1999) found a lack of genetic variation among Salton Sink wild populations, possibly due to increased pupfish abundance and gene flow after declines observed in the 1960s.

4.0 Reasons for Decline Around the Salton Sea

One possible cause of the decline of the desert pupfish around the Salton Sea is the introduction and establishment of several exotic tropical species that prey on or compete with desert pupfish for food and space (Black 1980). Interactions with introduced mosquitofish (*Gambusia affinis*) contribute to the decline of pupfish (Evermann 1930; Jennings 1985). The sailfin molly (*Poecilia latipinna*) was first discovered in the late 1950s in irrigation drains (Black 1980) and has become established in the Salton Sea (Moyle 1976). Zill's cichlid (*Tilapia zillii*) and the Mozambique mouthbrooder, *T. mossambicus*, were introduced into the

Salton Sea in the late 1960s and early 1970s to control aquatic weed growth in the irrigation canals and drains (Black 1980).

Selenium is carried by irrigation water from deposits in the upper Colorado River basin to the fields of the Imperial Valley. It is concentrated in the soils by evaporation and results in high levels of selenium in the effluent from underground tile drains. The irrigation drains receive tile drainwater and contain selenium levels which exceed federal standards. A recent study by Bennett (1998) quantified whole-body selenium concentrations in a surrogate species for the pupfish, the sailfin molly. Mollies in 15 percent of the drains had selenium levels exceeding the reproductive toxicity threshold of 6 ppm for warmwater fishes. Bennett (1998) concluded that desert pupfish were apparently at reproductive risk in many of the drains where they occur.

Other factors responsible for declines in desert pupfish populations around the Salton Sea include habitat modification due to water diversions and ground water pumping for agriculture (Pister 1974; Black 1980). Aerial pesticide application is a common practice around the Salton Sea which may also affect pupfish populations (Marsh and Sada 1993). There is also concern that introduced saltcedar (Tamarisk) adjacent to pupfish habitat may cause a lack of water at critical times due to evapotranspiration (Marsh and Sada 1993).

5.0 Conclusions

Historical accounts indicate that the desert pupfish was once widespread and abundant around the Salton Sea. General life history and habitat requirements of pupfish are fairly well known, but detailed life history information is required to determine characteristics of desert pupfish population dynamics. For example, habitat preference is required to determine the viability and status of native populations, to develop delisting criteria, and rehabilitate habitats so they are better suited to desert pupfish than to non-natives (Marsh and Sada 1993).

There are other gaps in our knowledge of desert pupfish. There are conflicting reports on recent trends in pupfish populations which can only be resolved with a systematic monitoring program. Also, the high temporal and spatial variability in numbers of pupfish collected in recent surveys suggests that desert pupfish may move among habitats. If movements do occur, there needs to be an understanding of why these movements occur. Quantification of the effects of non-native species on desert pupfish would provide information to assist in managing native and refugium habitats. This would require understanding the life history and habitat requirements of all non-native species in the Salton Sea determine areas of niche overlap and identify which non-native species impact desert pupfish. This would permit implementation of management actions to enhance pupfish but discourage or eliminate non-native species. The effects of high selenium levels on pupfish reproduction are also unknown. Finally, genetic variation among Salton Sea pupfish populations needs to be monitored to follow genetic trends and determine requirements to maintain viable populations.

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