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Review of the Fisheries of the Salton Sea, California, USA: Past, Present, and Future

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ABSTRACT: The Salton Sea is an endorheic, 980-km^2 salt lake in the Sonoran Desert of southern California. The historical fish community switched from freshwater to marine species as salinity increased due to evaporation and brackish water inflows. Three species, bairdiella (*Bairdiella icistia*), orangemouth corvina (*Cynoscion xanthulus*), and sargo (*Anisotremus davidsoni*), established from introductions beginning in 1929. Thirty-four marine fish species from the northern Gulf of California were introduced between 1929 and 1956. During the late 1960s and early 1970s, a hybrid tilapia (*Oreochromis mossambicus* × *O. urolepis hornorum*) invaded the Salton Sea and became dominant by numbers and weight. Research has shown that nearshore and estuarine areas have the highest catch rates of tilapia (over 11 kg/50 m net/h). Orangemouth corvina, bairdiella, sargo, and the hybrid tilapia grew faster, but had shorter life spans than conspecifics elsewhere, and Salton Sea conspecifics of 50 years ago. All four species aggregated along the nearshore and estuarine areas in the summer for reproduction and relief from low oxygen conditions in the pelagic areas of the marine lake. Restoration alternatives for the Salton Sea must recognize the value of estuarine and nearshore areas as essential fish habitats for the Salton Sea fisheries ecosystem.

KEY WORDS: Salton Sea, bairdiella, orangemouth corvina, tilapia, restoration, salt lakes.

I. HISTORY OF THE SALTON SEA

The Salton Sea is an endorheic (closed basin), 980-km^2 desert salt lake bounded by the Gulf of California to the south, the Colorado River to the

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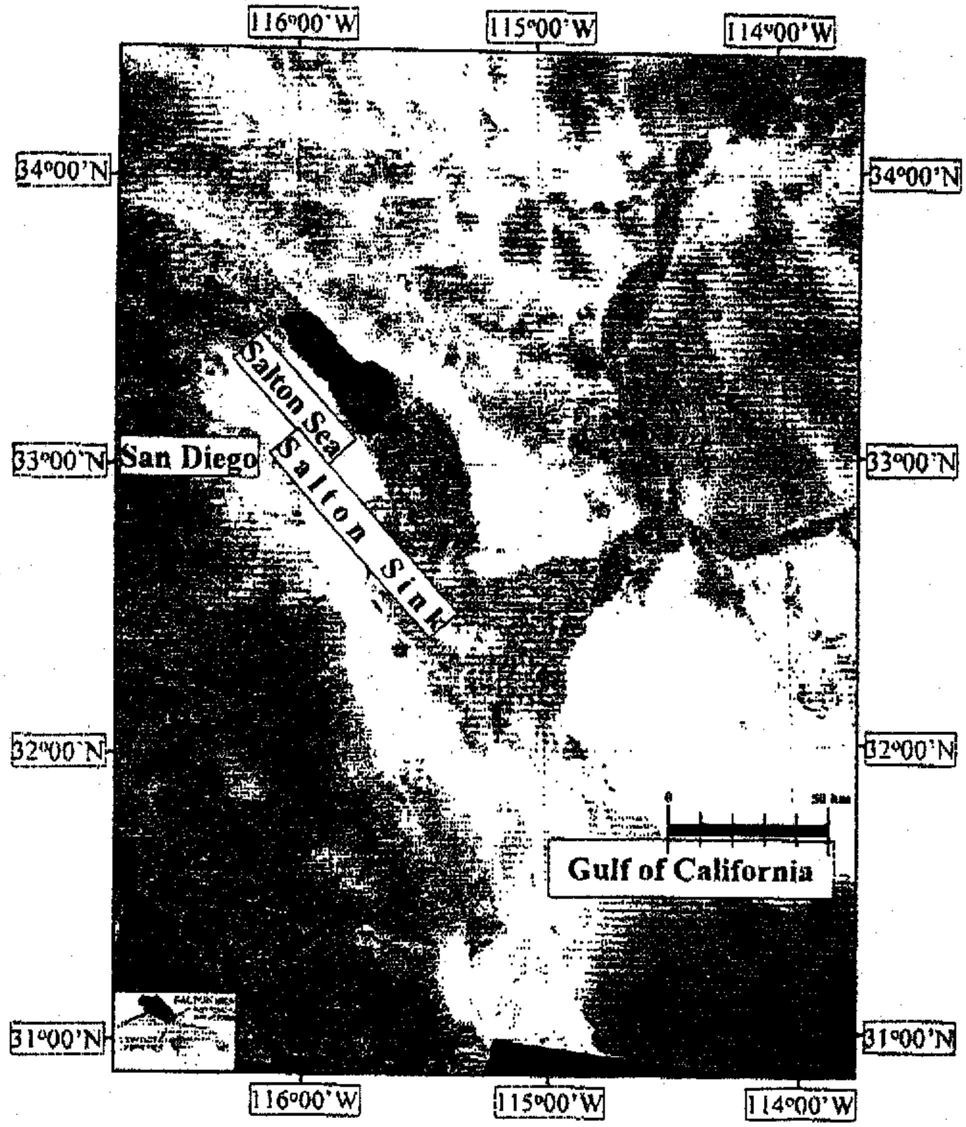

FIGURE 1. The Salton Sea in relation to the Gulf of California and the Salton Sink (from the Salton Sea Database— University of Redlands, California).

Riedel, 2000), but a further increase in salinity may have adverse effects on reproduction (Hickling, 1963; Chervinski and Yashouv, 1971; Perry and Avault, 1972), recruitment (Hodgkiss and Man, 1977), and growth (Chervinski and Zorn, 1974; Payne, 1983; Payne and Collinson, 1983). Increasing salinities have been reported to impact fish reproduction and recruitment in the Sea. Laboratory studies by Mitsui et al. (1991a) showed that sargo spawned when acclimated to 45 g/l water but all larvae died. Orangemouth corvina (*Cynoscion xanthulus*), acclimated to 35 to 40 g/l, spawned successfully when injected with leutinizing hormone-releasing hormone *a* (Thomas et al., 1994); but fish acclimated to 45 to 50 g/l failed to spawn even when induced. Simmons (1957) found that corvina in Laguna Madre, TX tolerated 70 g/l but did not spawn. Brockson and Cole (1972) concluded that the optimal salinity range for orangemouth corvina was 33 to 37 g/l. Mitsui et al. (1991b) sampled 11 Salton Sea stations over 3 years enumerating late egg and early larval stages of orangemouth corvina, bairdiella (*Bairdiella icistia*) and sargo (*Anisotremus davidsoni*). Eggs and larval numbers declined as salinity increased from 38 to 44 g/l from 1987 to 1989. Higher densities of larval fishes were found near the few freshwater inlets in the south of the Sea (New and Alamo Rivers).

All fish in the Sea are under stress due to the combination of high salinity, accelerated eutrophication, and dramatic water quality fluctuations. Fish may be dying due to regular infusions of deoxygenated water and toxic levels of ammonia and sulfide from infrequent lake turnovers that combine with high and low temperature stresses (Carpelan, 1961b). Parasitic dinoflagellates have been found attached to tilapia gills. The fine structure of tilapia gill filaments is 'clubby', which probably is due to one or more of the above stresses and likely decreases respiratory efficiency (Kuperman and Matey, 1999; Kuperman et al., 2001).

At present, the Sea is used primarily for recreation and as a repository for agricultural wastewaters. The Sea is designated by the state of California as a repository for nutrient-rich drainage waters from several commercial farms in the Imperial Valley. As a result, it has high primary productivity, which in turn accounts for the high productivity of its fishery (Black, 1974, 1988). In 1971, the California Department of Fish and Game (CDFG) recorded recreational fish catches at the Sea at 1.88 fish/angler/h, one of the highest catch rates recorded in the state (CDFG, 1971).

Recreational use of the Sea peaked in the 1950s. Fueled by the productive fishery, angling soared after World War II. Golf courses, marinas, and yacht clubs multiplied along the Sea shores. After the

TABLE 2

Fish Introductions to the Salton Sea from 1929 to 1956 (Reproduced from Walker et al. 1961)

Date (dd/mm/yy)	Number	Species	Common Name	Origin
20/10/29	900	*Morone saxatilis*	striped bass	Tracy California
24/10/29	1500	*Morone saxatilis*	striped bass	Tracy California
21/10/30	1800	*Morone saxatilis*	striped bass	Tracy California
13/11/30	500	*Gillichthys mirabilis*	longjaw mudsucker	San Francisco Bay
13/11/34	15000	*Oncorhynchus kisutsh*	silver salmon	San Diego Bay
02/10/48	43	*Anchoa mudeoloides*	anchovy	Not specified
23/12/48	1000	*Cetengraulis mysticetus*	anchoveta	Guaymas
	12	*Caranx caballus*	green jack	San Diego coast
10/05/50	5000	*Cetengraulis mysticetus*	anchoveta	San Diego coast
12/05/50	29	*Albula vulpes*	bonefish	San Felipe
	2	*Cetengraulis mysticetus*	anchoveta	San Felipe
	1	*Paralichthys aestuarius*	halibut	San Felipe
	40	*Colpichthys regis*	silverside	San Felipe
	1	*Eucinostomus argenteus*	spotfin mojarra	San Felipe
	2	*Trachinotus paitensis*	paloma pompano	San Felipe
	27	*Cynoscion xanthulus*	orangemouth corvina	San Felipe
	14	*Cynoscion parvipinnis*	shortfin corvina	San Felipe
	1	*Cynoscion macdonaldi*	totuava	San Felipe
	7	*Menticirrhus undulatus*	California corbina	San Felipe
	1	*Menticirrhus nasus*	corbina	San Felipe
	15	*Micropogon mealops*	croaker	San Felipe
	57	*Bairdiella icistia*	bairdiella	San Felipe
14/12/50	25	*Mugil curema*	white mullet	San Felipe
	600	*Colpichthys regis*	silverside	San Felipe
	1	*Paralichthys woolmani*	halibut	San Felipe
	1	*Scomberomorus concolor*	Monterey Spanish mackerel	San Felipe
	1	*Menticirrhus undulatus*	California corbina	San Felipe
	12	*Eucinostomus argenteus*	spotfin mojarra	San Felipe
		Eucinostomus gracilis	mojarra	San Felipe
15/12/50	15	*Mugil cephalus*	striped mullet	San Felipe
	60	*Mugil curema*	white mullet	San Felipe
	70	*Colpichthys regis*	silverside	San Felipe
	1	*Nematistius pectoralis*	roosterfish	San Felipe
	1	*Menticirrhus undulatus*	California corbina	San Felipe
	75	*Eucinostomus argenteus*	spotfin mojarra	San Felipe
		Eucinostomus gracilis	mojarra	San Felipe
28/03/51	30	*Cetengraulis mysticetus*	anchoveta	San Felipe
	300	*Leuresthes sardina*	grunion	San Felipe
	3	*Cynoscion xanthulus*	orangemouth corvina	San Felipe
	2	*Cynoscion parvipinnis*	shortfin corvina	San Felipe
31/03/51	48	*Albula vulpes*	bonefish	San Felipe
	6	*Anchoa mundeoloides*	anchovy	San Felipe
	8	*Cetengraulis mysticetus*	anchoveta	San Felipe
	5	*Mugil curema*	white mullet	San Felipe
	3	*Colpichthys regis*	silverside	San Felipe

failure and a striped mullet population destined to disappear. A remnant striped mullet population still exists in the Sea (Riedel et al., 2001).

Longjaw mudsuckers were introduced to the Sea in 1930 from San Diego Bay to provide a bait fishery (Walker et al., 1961; Table 2). The natural range for longjaw mudsuckers is from central California to the Gulf of California. Spawning of longjaw mudsucker peaks in January and February (Walker et al., 1961). Adult distribution is mostly along the shore in association with embayments and cover (Walker et al., 1961). Longjaw mudsuckers are captured in those areas today and are used for bait in the orangemouth corvina sportfishery.

Threadfin shad (*Dorosoma petenense*) were introduced in the Colorado River from Tennessee in 1953 (Kimsey, 1954; Table 2). The fish spread from the Colorado River to the canal systems of the Imperial Valley and into the Sea. Threadfin shad was first captured at the Sea in 1955 mostly in association with the incoming tributaries (Hendricks, 1961a). Salton Sea threadfin shad diet has been observed to be mostly phyto- and zooplankton (Hendricks, 1961a). Threadfin shad are important forage fish, having been commonly observed in orangemouth corvina stomachs (Hendricks, 1961a).

Desert pupfish is the only fish native to the Salton Sea and endemic to the Salton Sink (Baird and Girard, 1853; Shoenherr, 1988). Desert pupfish prefer low energy, shallow water habitats rich in structures such as rooted vegetation (Marsh and Sada, 1993). They can survive extreme conditions of salinity and dissolved oxygen, as well as extreme variations in those conditions (Lowe and Heath 1969). Desert pupfish were reported abundant at the Sea, with over 10,000 individuals in a single shoreline pool (Barlow, 1961). The desert pupfish was listed as endangered by the sate of California in 1980 (CDFG 1980) and federally in 1986 (FWS 1986) because of habitat alterations and contamination, and invasion of exotics (FWS 1986). Fish surveys during the 1950s and 1960s indicated that desert pupfish are declining (Schoenherr, 1979), possibly due to introduction of exotic species, reproductive failures due to selenium toxicity, and habitat modifications (Black, 1980; Bennett, 1998).

B. HYPERSALINE PHASE (MID 1960s - PRESENT)

This phase includes the period during which tilapia established in the lake. In 1964 to 1965, the hybrid tilapia (*Oreochromis mossambicus* × *O. urolepis hornorum*) escaped to the Sea by two routes: (1) an aquarist fish farm near Niland (St Amant, 1966), and (2) from irrigation ditches where it was stocked purposefully by California and Arizona fisheries agencies for the control of nuisance aquatic weed and insect species (Costa-Pierce

TABLE 3

Temperature and Salinity Tolerances for Adult *Oreochromis mossambicus* Adapted from Costa-Pierce and Riedel (2000).

	Effects	References
Temperatures (°C)		
5.5	Total mortality	Li et al., 1961
8–10	Total mortality	Chimits, 1957
8.3–9.4	Total mortality	Kelly,1956
8-10	Low temperature tolerance limits	Chervinski, 1982
11	Total mortality after 5 d at this temperature	Allanson et al., 1962
11	Survived at 5‰	Allanson et al., 1971
12	Survives this extreme temperature by inhabiting the estuarine area of the Kowie River, South Africa	Allanson et al., 1971
15	Suffer from cold stress	Caulton, 1978
15	Cold stress and fungal infections occurred	Al Amoudi et al., 1996
Below 20	Severe *Saprolegnia* infection if exposed beyond 120 hours	Allanson et al., 1971
Salinities (ppt/L)		
14	Highest growth rate at 28°C	Payne et al., 1988
30	Grew well; reproduced in ponds	Chimits, 1957
30	Reproduced in ponds	Vaas and Hofstede, 1952
49	Reproduced	Popper and Lichatowich, 1975
61	Gradual transfer allowed successful adaptation	Dange, 1985
40–55	Grew and reproduced	Riedel et al., 2001
120	Adapts well to gradual changes in salinities	Whitfield and Blaber, 1976

Riedel et al. (2001) also report a strong preference between the surface and bottom of the lake for tilapia and bairdiella at different times in the year (Figure 4). In the summer, the few fish that remain in the pelagic area move toward the surface, possibly to minimize the detrimental effects of oxygen deprivation. In the winter, fish tend to remain near the bottom to feed on the abundant pile worms (Carpelan and Linsley, 1961).

There is evidence that Salton Sea fish are a fast growing, shorter-lived population. Riedel et al. (2001) report faster growth and shorter life spans for Salton Sea fish than conspecifics elsewhere and conspecifics of the first introductions decades ago (Table 6; Figure 5).

1. Tilapia

Tilapias are native to Africa (Trewavas, 1983). Because of their importance in aquaculture, tilapia, especially *O. mossambicus*, are the most

TABLE 5

Catch per unit effort (kg/ 50 m net/h) ± SEM by area and season for fish sampled from the Salton Sea, CA between 1999 and 2000

	1999			2000		
	Nearshore	Pelagic	Estuarine	Nearshore	Pelagic	Estuarine
Orangemouth Corvina						
Spring	3.03 ± 1.38	0.03 ± 0.01	0.45 ± 0.21	3.74 ± 1.29	0.04 ± 0.03	3.90 ± 1.46
Summer	0.32 ± 0.14	0.01 ± 0.01	0.42 ± 0.21	0.79 ± 0.36	0	0.37 ± 0.15
Fall	0.48 ± 0.47	0.02 ± 0.02	0.27 ± 0.16	0.05 ± 0.05	0	3.59 ± 2.30
Winter	0.45 ± 0.30	0.08 ± 0.06	0.02 ± 0.02	4.77 ± 2.18	0	1.60 ± 1.30
Bairdiella						
Spring	0.12 ± 0.03	0.37 ± 0.08	0.21 ± 0.10	1.55 ± 0.51	0.10 ± 0.04	0.14 ± 0.11
Summer	0.73 ± 0.14	0.15 ± 0.06	0.56 ± 0.12	0.62 ± 0.01	0.01 ± 0.01	0.58 ± 0.20
Fall	0.30 ± 0.09	0.06 ± 0.03	0.84 ± 0.24	0.12 ± 0.06	0	0.40 ± 0.26
Winter	0.04 ± 0.02	0.05 ± 0.03	0.08 ± 0.03	0	0.15 ± 0.06	0.01 ± 0.01
Tilapia						
Spring	1.01 ± 0.20	0.29 ± 0.90	1.09 ± 0.29	1.56 ± 0.89	0.02 ± 0.01	1.44 ± 0.57
Summer	6.65 ± 1.35	0.14 ± 0.06	12.3 ± 4.70	0.90 ± 0.41	0.02 ± 0.01	3.48 ± 1.16
Fall	2.93 ± 1.50	0.01 ± 0.06	11.4 ± 3.60	3.34 ± 0.84	0.02 ± 0.01	1.08 ± 0.50
Winter	0.28 ± 0.08	0.17 ± 0.05	1.13 ± 0.40	1.59 ± 0.80	0.03 ± 0.01	1.70 ± 0.96
Number of observations						
Spring	8	12	4	8	12	6
Summer	16	24	8	8	11	6
Fall	8	12	4	8	12	6
Winter	16	24	9	8	12	6

From Riedel et al. 2001.

widely distributed exotic fish worldwide. Research on tilapia in the United States has been conducted on their use as food, vegetation control, and game fish (Dill and Cordone, 1997; Costa-Pierce and Rakocy, 1997, 2000). Tilapia have become established in all subtropical regions of the United States (Costa-Pierce and Riedel, 2000) and are an ecological problem in most ecosystems where they invaded (Courtney et al., 1984; Courtney, 1997; Courtney and Stauffer, 1990). *O. mossambicus* are presently found in coastal regions of southern California, and the Salton Sea and adjacent drains (Page and Burr, 1991; Dill and Cordone, 1997).

Tilapia are euryhaline (Suresh and Lin, 1992; Watanabe, 1997; Costa-Pierce and Riedel, 2000; Table 3), probably because they evolved from a marine ancestor (Myers, 1938; Trewavas, 1983), but are stenothermal (Hargreaves, 2000; Table 3). *O. mossambicus* can survive water temperatures 15 to 40°C, but grow optimally at 25 to 37°C (Al Amoudi et al., 1996). Tilapias cease to feed below 16°C (Kelly, 1956) and reproduce at

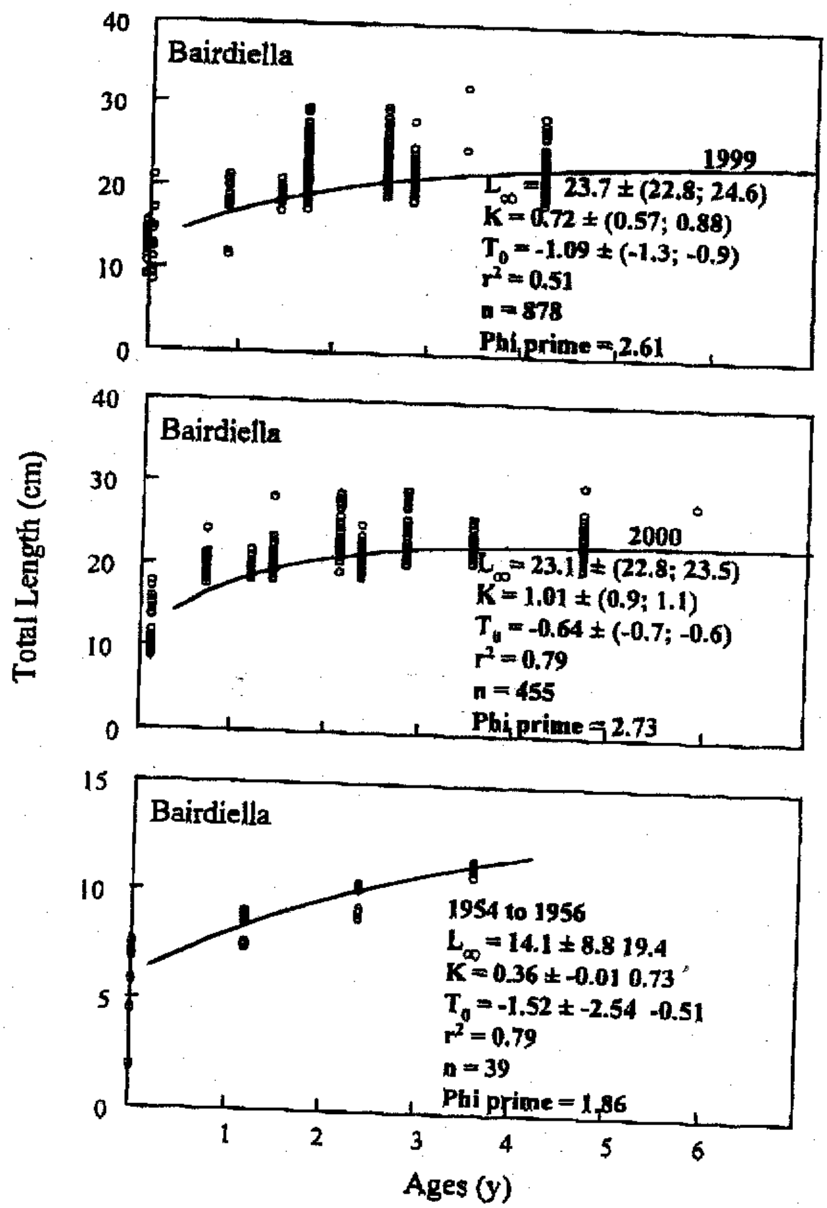

FIGURE 5. Von Bertalanffy growth function parameter estimates and phi prime growth performance indices (Moreau et al., 1986) for tilapia (*Oreochromis mossambicus* × *O. urolepis hornorum*), bairdiella (*Bairdiella icistia*), orangemouth corvina (*Cynoscion xanthulus*), and sargo (*Anisotremus davidsoni*) captured in the Salton Sea, California during 1999 and 2000. Numbers in parenthesis are lower and upper 95% confidence intervals of parameter estimates (from Riedel et al., 2001).

TABLE 6

Age (y) and Mean Total Length (cm) ± One Standard Deviation for Salton Sea Fish Sampled in 1999 and 2000 Compared with Salton Sea Fish Sampled in the Mid-1950s and Conspecifics Sampled Elsewhere

	N	Age	Mean total length ± SD	Mean total length from other studies	Ref.
Bairdiella	52	0+	13.0 ± 2.2	-	
	36	1+	18.6 ± 2.0	13.1	Whitney, 1961a
	606	2+	21.2 ± 2.0	15.4	ditto
	184	3+	22.4 ± 2.3	17.2	ditto
	2	4+	28.5 ± 5.3	17.3	ditto
Orangemouth corvina	9	0+	28.4 ± 8.0	-	
	62	1+	46.1 ± 11.6	11.0	Whitney, 1961b
	115	2+	65.9 ± 6.0	40.0	ditto
	10	3+	69.6 ± 4.9	50.2	ditto
	-	4+			
	-	5+			
	1	6+	83.0	-	
Sargo	32	0+	15.6 ± 1.5	-	
	2	1+	18.5 ± 0.4	-	
	33	2+	27.5 ± 1.4	-	
	-	4+		25.0	Love, 1996
	-	12+		32.5	ditto
Tilapia	404	0+	8.0 ± 2.7	5.8	Khoo and Moreau, 1990
	-	1+			
	-	2+			
	2828	3+	29.2 ± 1.8	25.0	Khoo and Moreau, 1990
				25.0	Roux, 1961
				20.6	Hecht, 1980
				15.0	Koura and Bolock, 1958
	1314	4+	30.6 ± 2.5	26.0	Khoo and Moreau, 1990
				30.0	Roux, 1961
				25.5	Hecht, 1980
				18.0	Koura and Bolock, 1958
	292	5+	32.9 ± 2.9	28.5	Khoo and Moreau, 1990
				32.5	Roux, 1961
				23.4	Hecht, 1980

Dashes indicate no data. (from Riedel et al. 2001).

water temperatures only above 20 to 22°C (Chervinski, 1982; Philippart and Ruwet, 1982). At temperatures less than 25°C, routine metabolism (as measured by oxygen uptake rates) and growth rates decrease rapidly (Caulton, 1978). Laboratory experiments showed a sharp depression of growth for tilapia kept at 20 to 22°C compared with tilapia at 25 to 28°C (Chmilevskii, 1998). Onset of cold stress has been widely reported for *O. mossambicus* at water temperatures of 15°C and below (Allanson

Costa-Pierce (1998) suggested that the Salton Sea tilapia "strain" may be an important partner in genetic improvement programs for saltwater tilapia aquaculture (Watanabe et al., 1997). Because avian botulism, *Vibrios* and *Streptococcus* having been found in and on the Salton Sea tilapia, use of this potentially valuable strain, or movements of this fish outside of the Sea, is not at present recommended. In addition, the Salton Sea tilapia could have potentially harmful environmental impacts on sensitive, enclosed marine ecosystems such as the northern Gulf of California biosphere reserve.

2. Bairdiella

Bairdiella (family Sciaenidae) are native to the Gulf of California, where they inhabit estuarine and coastal areas (Walker et al., 1961; Johnson, 1978) and support commercial and sport fisheries (Jacob, 1948; Longhurst, 1964). Bairdiella rarely grows longer than 30 cm and is an important forage fish for the orangemouth corvina (Whitney, 1961a). *Bairdiella* spp has a wider distribution, occurring in the eastern Pacific and western Atlantic (Sasaki, 1989).

Fifty-seven croakers were introduced in 1950 into the Salton Sea, followed by the introduction of another 10 fish in 1951 (Walker et al., 1961; Table 2). The first account of a Salton Sea bairdiella was made in 1953 (Dill and Cordone, 1997).

The Altantic croaker tolerates salinities ranging from freshwater to 45 g/l (Simmons, 1957) and temperatures between 5°C (Perret et al., 1971) to over 34°C (Kilby, 1955). The Salton Sea bairdiella has a high salinity tolerance. The Atlantic croaker (*Bairdiella chrysoura*), has been found to grow well at 45 g/l in Laguna Madre, TX (Simmons, 1957). There is relatively little recent research on spawning habits of the croaker, but most of what is known follows the classic descriptions of croaker spawning recorded by Kuntz (1914), Welsh and Breder (1923), and Walker et al. (1961).

Whitney (1961a) reported that Gulf croakers have distinct inshore-offshore portions of their life history related to feeding and reproduction. Fish are known to move inshore in May and offshore in September following the abundance of pile worms (*Neanthes succinea*). Mok and Gilmore (1983) report peak spawning to occur between March and June for the Altantic croaker. Bairdiella from the Salton Sea have been reported to mature in 1 to 2 years and spawn in May and early June (Haydock, 1971); grow to a maximum of 30 cm (Walker et al., 1961); and have a life span of up to 8 years (Lattin, 1986).

Beckwitt (1987) reported high genetic variability for Salton Sea bairdiella, suggesting potential adaptation to environmental change depopulation in the Sea at 1 to 3 million fish (Hulquist, 1970). Adult orangemouth corvina are readily caught by anglers in the nearshore of the Sea. Maximum reported size is 32 pounds (Hulquist, 1970). Orangemouth corvina grow very rapidly in the Sea in comparison with other conspecifics (Blake and Blake, 1981; Warburton, 1969; Table 6). Orangemouth corvina play a valuable ecological role as the most successful top carnivore in the Sea.

4. Sargo

Sargo are distributed from central to southern Baja California and into the northern Gulf of California. Sixty-five sargo were introduced in the 1950s from the northern Gulf of California into the Salton Sea (Walker et al., 1961; Table 2). Sargo are a schooling species preferring shallow subtidal habitats. They mostly congregate around structures. Spawning of sargo occurs mostly during late spring and throughout summer (Love, 1996). The eggs are pelagic and the juveniles migrate inshore where they may congregate with juveniles of other species. Sargo are demersal, feeding mostly on benthic invertebrates (Love, 1996). Sargo are occasionally reported by Salton Sea anglers mostly as incidental catch.

The fish biology, behavior, and fisheries for sargo are little known in the Salton Sea. Sargo are closely related to Pacific porgies (Family Sparidae), salema, and Pacific flagfin mojarras (Family Gerreidae). Sargo are larger than croaker (reaching 2 kg) and are important gamefish in the Sea. It is assumed this fish is also prey for the orangemouth corvina (Walker et al., 1961).

IV. THE FUTURE OF THE SALTON SEA

Because of the ecological and recreational importance of the Salton Sea several restoration approaches (Table 7) are being contemplated. Restoring the Sea is an open-ended proposition because the lake progressed from freshwater to hypersaline, never stabilizing at environmental conditions that could be used as a target baseline for restoration. The objectives of restoration plans are, however, to keep the lake as a viable ecosystem to support migratory and resident biota, continued use as an agricultural wastewater repository, control of salinity and elevation, prevention of fish and wildlife die offs, and promotion of recreational opportunities (Borrego et al., 1999; SSA, 2000). Many restoration objectives may be conflicting and a prioritization taking into account ecological, societal, and financial interests is underway.

Alternatives 1 and 2

1.36	- Fish Harvesting - Improve recreational facilities - Shoreline cleanup - Wildlife disease control - North wetland habitat	150 kaf/y EES (showerline technology)			
1.06	Same as above	Same as above	Displacement dike import flood flows	Import CASI water (up to 304.8 kaf/y, as required)	Same as above
0.80	Same as above	Same as above	Same as above	Same as above	Additional displacement inflow
Future inflow scenario (maf/y)	2003	2008	2015	2030	2060

Alternative 5					
1.36	- Fish Harvesting - Improve recreational facilities - Shoreline cleanup - Wildlife disease control - North wetland habitat	150 kaf/y EES in-Sea evaporation pond (N)		Export – 150 kaf/y	
1.06	Same as above	Same as above	Displacement dike import flood flows	Import CASI water (up to 304.8 kaf/y, as required)	Same as above
0.80	Same as above	Same as above	Same as above	Same as above	Additional displacement inflow

Notes: Maf/l = Millions acre-feet/year; kaf/y = thousands acre-feet/year; EES = enhanced evaporatoin system.

1995; Shields et al., 1995; Kirchhofer, 1996; Whitfield, 1996; Wriedt and Schulz, 1997). It is likely that the Salton Sea biota will change after restoration plans are underway. An understanding of the fisheries ecology concomitant with these changes is pivotal to provide early warnings of the effects of restoration practices. Restoration practices may be successful in controlling salinity, but if detrimental effects on the fisheries are experienced, the Salton Sea may lose its importance as a wildlife sanctuary and recreational lake.

Implementation of a tilapia commercial harvesting at the Sea may benefit the economy of the surrounding communities. The Salton Sea harbors what is likely the largest unfished tilapia population in the world. When exploiting a virgin fish resource, younger, faster growing individuals benefit from the harvest of older, slower growing fish (Schaefer, 1954; Hilborn and Walters, 1992), and incidence of diseases (and possibly periodic die-offs) may be decreased. Given the large tilapia biomass in the Sea, fishery products may be commercialized as meals, food, or fertilizers. Given the high estimates of fish gill net catch rates (Riedel et al., 2001), the fishery may also benefit local communities, but more research needs to be completed to determine turnover rates, yields per recruit estimates, and overall sustainability of the fishery resources. Managing the Salton Sea for a sustained fishery is not only ecologically desirable but may be economically attractive.

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