SALTON SEA ECOSYSTEM RESTORATION PLAN

Evaluation of Salinity Tolerance and Availability of Selected Fish Species Potentially Suitable for Introduction to the Salton Sea

June 2005

Table of Contents

Table

Appendix

EVALUATION OF SALINITY TOLERANCE AND AVAILABILITY OF SELECTED FISH SPECIES POTENTIALLY SUITABLE FOR INTRODUCTION TO THE SALTON SEA

The California Resources Agency is preparing a Salton Sea ecosystem restoration study and accompanying programmatic environmental impact report in compliance with legislation enacted in 2003. As part of this process, it is anticipated that one or more of the ecosystem restoration alternatives will include stabilization of the salinity in the Salton Sea as an important component of the management strategy. It also is recognized that the salinity levels in the Salton Sea could exceed the tolerance limits for many of the fish species currently occupying the Sea prior to implementation of the an ecosystem restoration plan, and that fish introductions might be necessary to re-establish a fish community in the Salton Sea.

The primary purposes of this report were to identify an initial list of fish species that might be suitable for introduction to the Salton Sea under future ecosystem restoration alternatives, identify and summarize available information on their salinity tolerance, and conduct a preliminary investigation of the availability of Salton Sea fish species in the Gulf of California for collection and introduction into the Salton Sea. This assessment was not exhaustive; instead, it was intended to develop reasonable expectations about the success of a future fishery in the Salton Sea prior to developing and analyzing ecosystem restoration alternatives.

Based on this assessment, it was concluded that:

- Several fish species, including those recently abundant in the Salton Sea, likely could be successful in the Salton Sea under restored conditions
- Factors other than salinity (e.g., water quality) will influence the success of any future fish community in the Salton Sea
- Introduced marine fish species (i.e., orangmouth corvina, sargo, and Gulf croaker) currently or recently abundant in the Salton Sea likely still persist in the Gulf of California in sufficient numbers to stock the Salton Sea, if necessary, following restoration
- International, federal, state, and local regulations are not likely to preclude future collection and introduction of these species
- Future implementation of a stocking program would require careful consideration of the consequences of the introduction, particularly if species other than those previously successful in the Salton Sea are considered

POTENTIALLY SUITABLE FISH SPECIES

For identifying fish species potentially suitable for future introduction into the Salton Sea, habitat preferences, water quality tolerances, diet and forage base requirements, and historical fish population success at the Salton Sea were considered. The preliminary analysis was based on following key assumptions.

- Stabilized salinity associated with ecosystem restoration alternatives could range from that of seawater to the current salinity levels.

- Other factors influencing fish and invertebrates at the Salton Sea (e.g., selenium, anoxia, ammonia) will not be limiting.
- Any future fish assemblage must provide a forage base for piscivorous birds and, to the extent possible, a recreational fishery.
- Any future fish community must be self-sustaining over the long term (e.g., not require sustained hatchery operations to maintain the population), although it is recognized that hatcheries or similar facilities likely would be required to acclimate fish to conditions at the Salton Sea as part of the introduction process.
- Any future fish assemblage must not threaten the continued persistence of desert pupfish (*Cyprinodon macularis*) at the Salton Sea.
- Currently important invertebrate forage species, such as pileworms, would be represented in the Salton Sea under future restoration alternatives that include stabilized salinity.
- Current marine fish species (orangemouth corvina, sargo, and Gulf croaker) could be lost at the Salton Sea before restoration is implemented and salinity is stabilized.
- Certain fish species, such as tilapia, currently occupying the Salton Sea would be components of any future fish assemblage.
- Fish species that are candidates for future introduction must be available in quantities necessary to support a stocking program.
- The future configuration of the Salton Sea will support estuarine and deeper water habitats, as feasible.

Approach

Current conditions at the Salton Sea have possibly affected several major sport fish species, which now have reached undetectable densities within the last year. The approach used to choose fish species and assemblages that are candidates for introduction (re-introduction) recognized that there likely would be a gradual evolution of water quality following the implementation of the selected ecosystem restoration alternative and that some of these historically important species might not rebound without an active restocking program.

Species were identified based on the goal of providing a sustainable forage base for piscivorous birds; however, species that could support a recreational fishery also were considered. In addition, consideration was given to species that would have representation at various trophic levels and that would contribute to the overall stability of the Salton Sea ecosystem.

The primary criteria for selecting potential species appropriate for future Salton Sea conditions were:

- High tolerance for environmental variability (salinity, dissolved oxygen, suspended solids, temperature)
- High feeding plasticity (able to switch preferred foods as food web changes or evolves; able to eat a wide variety of foods)
- Suited to the unique set of habitats available at the Salton Sea (e.g., shallow, warm water with freshwater and estuarine connections)

To identify appropriate candidates for potential future introduction (or re-introduction) to the Salton Sea, fish communities from other water bodies that might tolerate conditions in the Salton Sea were reviewed. Because the Salton Sea is a unique, inland marine ecosystem substantially different than saline lakes throughout the West, these saline lakes did not offer a useful source of species for consideration in future Salton Sea restoration. Many saline lakes (e.g. Great Salt Lake, Mono Lake) are too saline for fish survival. Alkaline lakes, such as Pyramid, Eagle, and Carson, support unique coldwater, salmonid fisheries that would not be able to sustain viable populations in the Salton Sea because of the higher salinity, the warmer water, and the lack of spawning habitat. Some possible marine fish assemblages, such as obligate benthic species that require good water quality, also were rejected because of their unlikely success in the conditions of the Salton Sea. Therefore, the initial search for species that could serve as candidates for the Salton Sea focused on the Gulf of California and nearby coastal marine habitats. In addition, several Atlantic coastal fish species, particularly from the Gulf of Mexico, that also are potential candidates were identified.

Potential Fish Candidates and Assemblages

Certain fish species currently occupying the Salton Sea are expected to persist in the future and not require re-introduction. Therefore, these species likely would be a component part of any future fish assemblage. Tilapia (*Oreochromis mossambicus*) are currently abundant in the Salton Sea and are expected to be important members of any future assemblage. Several minor species have been observed in recent samples and could persist in the Salton Sea at unknown levels under future scenarios. These include threadfin shad (*Dorossoma petenense*) and striped mullet (*Mugil cephalus*) from estuarine and nearshore areas (Riedel et al. 2003). In addition, redbelly tilapia (*Tilapia zillii*) (in low numbers), longjaw mudsucker (*Gillichthys mirabi*) (in freshwater/estuarine), and desert pupfish are expected to be present in all future assemblages. Invertebrates such as pileworms, amphipods, and other benthic species are important as a forage base for Salton Sea fish now and would be under future scenarios.

In addition to the four fish species currently or recently abundant in the Salton Sea (orangemouth corvina, Gulf croaker, sargo, and tilapia), the following fish species were initially identified as potentially suitable based on known distribution and attributes believed to be beneficial in the Salton Sea (e.g., foraging base for birds and potential sport fishery). Most of these species occur in the Gulf of California—the source of many of the fish species historically successful in the Salton Sea.

- Tilapia (*Oreochromis mossambicus*)
- Milkfish (*Chanos chanos*)
- Pacific flagfin mojarra (*Eucinostomus currani*)
- Anchoveta (*Cetengraulis mysticetus*)
- Gulf Croaker (*Bairdiella icistia*)
- Yellowfin croaker (*Umbrina roncador*)
- Salema (*Xenistius californiensis*)
- Porgy (*Calamus brachysomus*)
- Silver mojarra (*Eucinostomus argenteus*)
- Mexican goatfish (*Mulloidichthys dentatus*)
- Longfin salema (*Xenichthys xanti*)
- Bighead tilefish (*Caulolatilus affinis*)
- Longspine porgy (*Stenotomus caprinus*)
- Codlet (*Bregmaceros bathymaster*)
- Deepbody anchovy (*Anchoa compressa*)
- Blue bobo (*Polydactylus approximans*)
- Orangemouth corvina (*Cynoscion xanthulus*)
- Sargo (*Anisotremus davidsoni*)
- White sea bass (*Cynoscion nobilis*)
- Shortfin corvine (*Cynoscion parvipinnis*)
- Green jack (*Caranx caballus*)
- Pacific crevalle jack (*Caranx caninus*)
- White croaker (*Genyonemus lineatus*)
- Ocean whitefish (*Caulolatilus princeps*)
- Queenfish (*Seriphus politus*)
- Red Drum (*Sciaenops ocellatus*)

SALINITY TOLERANCE OF SELECTED SPECIES

Available information on the salinity tolerance of the species identified above, including selected invertebrate species, was compiled in the form of an annotated bibliography (Appendix A). The bibliography does not represent all of the information available on salinity tolerance of the identified species. It does, however, contain the majority of citations that were readily available regarding salinity tolerance of these species and adequately defines the salinity range under which those species can survive. Salinity references with information on temperature tolerance or tolerance to other environmental factors of particular importance to the Salton Sea also were included because of the importance of these parameters in selecting a future species assemblage.

Approach

The search was conducted through university libraries, internet search engines, electronic searches of various biological and environmental journals through their publisher's archives, and searches of other electronic databases. Additional information may be available in "gray literature," unpublished reports, or data collections at various universities or research institutions, particularly outside of the United States.

Results

The extent of salinity tolerance information varied substantially by the species reviewed. For those species that are cultured (e.g., tilapia and milkfish), tolerance information for salinity and other environmental factors is abundant in the available literature. For other species, especially those that that occur in the Gulf of California, salinity tolerance only could be inferred by the salinity ranges in which they occur in the wild. For most of these species, no salinity tolerance information was found in the literature. Absence of salinity data does not exclude these species from future consideration; however, additional research would be required to better define their potential to tolerate and thrive under conditions in a future Salton Sea.

The following salinity tolerance ranges are identified for those species for which information was readily available. Where the available information suggested that salinity tolerance varied by life history stage, the range is indicated for each life stage.

Table 1
Salinity Tolerance of Selected Species Potentially Suitable for Introduction to the Salton Sea (parts per thousand ‰)

Species	Eggs/Larvae	Juveniles	Adults
Tilapia	75-95 (max) 35-65 (optimal)	75-95 (max) 35-65 (optimal)	75-95 (max) 35-65 (optimal)
Milkfish	37 (max)	48-70 (max)	158 (max)
Sargo	40 (max) 33-37 (optimal)	45 (max)	45-55 (max) No Spawning
Orangemouth Corvina	40 (max) 33-37 (optimal)	45 (max)	50-55 (max)
Gulf Croaker	40 (max) 15-40	45 (max)	55-57 (max)
Green Jack	33.4-34 (larvae abundant)		
Red Drum	5-10 (cultured with no effect)	2-35 (survived confinement, transport)	
Anchoveta	34.4-34.8 (larvae abundant)		
Codlet	34.4-34.8 (larvae abundant)		
White Seabass		35-60 (juveniles found)	

AVAILABILITY OF SALTON SEA FISH SPECIES

The three marine fish species (orangemouth corvina, sargo, and Gulf croaker) recently abundant in the Salton Sea represent logical members of a future fish assemblage in the Salton Sea. These species successfully reproduced and survived in the Salton Sea environment and contributed to the forage base for fish-eating birds and the recreational fishery. However, under an assumption that these species could disappear from the Salton Sea prior to restoration, it was important to document their availability for possible re-introduction from other sources. Therefore, this report investigated the availability of orangemouth corvina, Gulf croaker, and sargo in the Gulf of California, and preliminarily identified the requirements associated with collecting, transporting, reintroducing these species in sufficient numbers to repopulate the Salton Sea. This reconnaissance-level evaluation was intended to answer the following questions regarding the feasibility of obtaining sufficient numbers for reintroduction:

- Do the three target fish species currently exist in the Gulf of California in sufficient numbers to provide an adequate supply to stock and repopulate the Salton Sea?
- What regulatory approvals/permits/compliance actions would be necessary with respect to Mexican laws and regulations in Mexican waters?
- What United States (e.g., U.S. Department of Agriculture, U.S. Fish and Wildlife Service) approvals might be needed?

Information on the availability of these species was obtained through literature review, internet search, and interviews with knowledgeable scientists and field biologists, regulatory officials, and commercial and sport anglers. No field visits or field studies were conducted as part of this investigation. To help determine the number of individuals of each species that would be necessary for stocking in the Salton Sea, original stocking records from DFG were reviewed.

Availability of Fish for Stocking

Fishing Fleets

Based on available information, the Gulf of California does not support a commercial fishery for the three target species and no harvest statistics were available. The larger "party boats" of anglers do not target orangemouth corvina, sargo, or Gulf croaker, fishing primarily for tuna species and billfish. However, they do report fairly large catches of miscellaneous species, with occasional reference to corvina in their catch reports.

Party boat captains interviewed indicated that fishermen at the Gulf of California often catch the three target species. Orangemouth corvina, sargo, and Gulf croaker are reported to be caught seasonally by shore or beach anglers. Fishing communities in Puerto Peñasco and Santa Clara in Sonora, Mexico and the coastal areas around San Felipe reported catches of "chano" (*Micropogonias megalops*), Corvina (*Cynoscion* spp.), "sierra" (*Scomberomorus* spp.), "tiburones" (*Carcharhinus* spp., *Mustelus* spp.), and "baqueta" (*Epinephelus acanthistius*). Joaquin Arvizu-Martinez[1] reported that corvina, mullet (*Mugil* spp.), sea bass (Serrunidae), snapper (Lutjanidae), porgies (Sparidae), and sierra are caught by fishermen in pangas along the coasts, with Mazatlan and Topolobampo being the main fishing ports of importance.

Other Sources

In addition to capturing wild stock, each of the target species may be a candidate for artificial production in a hatchery facility. The following are examples of programs that currently produce marine fish species.

[1] JOAQUIN ARVIZU-MARTINEZ, Centro Interdisciplinario de Ciencias Marinas, IPN, Apartado Postal 592, 23000 La Paz, Baja California Sur, Mexico

UABC Ensenada

The principle contact is David True Conal (e-mail: ctrue@uabc.mx) who operates a marine fish hatchery at UABC and is working on spawning and rearing marine fish from the Gulf of California. He is an expert in the acquisition of fishes of the family Sciaenidae, field handling, decompression and prophylaxis. Dr. Conal has done considerable work on the endangered *Totoaba macdonald*

Sea Center Texas

Sea Center Texas has semi-intensive fish production facilities for red drum and spotted seatrout available from March through November when fish are induced to spawn by manipulating water temperature and light then larval fish are transferred into ponds. Sea Center Texas is part of the Texas Parks and Wildlife. The contact person is Patty Cardoza at (979) 292-0100 or e-mail patty.cardoza@tpwd.state.tx.us.

Number of Fish Required

The cost to capture and transport live fish from San Felipe would include transportation, labor, equipment, fish transportation vehicles, hire of local fishermen, and construction of holding facilities. There is no set model or formula that can be used to estimate the numbers of individuals necessary to repopulate the Salton Sea; however, information in the original stocking efforts provides some insight.

Walker (1961)[2] reported that that DFG "made large plants of many species secured from the Gulf of California at San Felipe, Baja, California. The present populations (1961) of bairdiella, orangemouth corvina, and sargo resulted from the plantings." A "shotgun approach" was used to capture and stock these fish. Significant numbers of fish were captured without regard to species or age class. All fish captured were transported to the Salton Sea and released. The exact number of individual species is uncertain and no data on size or age class are available.

Data provided to Walker (1961) by John Fitch (DFG) indicate that no more than 270 orangemouth corvina, 70 Gulf croakers, and 70 sargo were stocked in the Salton Sea from May of 1950 through May of 1953. This suggests that relatively modest numbers of these fish would be required to stock and repopulate the Sea if conditions are restored to near what they were in the 1950s and 1960s. A few hundred of each species likely would be sufficient to replicate the original plantings that resulted in the former sport fishery of the Salton Sea; however, project–level analysis would be required to determine the details of the stocking program.

Regulatory Requirements

The following presents a brief summary of the regulatory requirements that would be required as part of a fish stocking program.

California Department of Fish and Game

DFG requires a permit, issued by the DFG Regional Office, to transport and stock fish in California.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service will likely require an evaluation of the potential impact of introduced or re-introduced fishes on endangered species resident at the Salton Sea and the drainages leading into the Salton Sea (e.g., desert pupfish). This biological assessment could lead to the need for a biological

[2] Walker, B.W., (ed.). 1961. The ecology of the Salton Sea, California, in relation to the sportfishery. Calif. Dept. Fish and Game, Fish Bull. 113. 204 pp.

opinion and endangered species take permit. The U.S. Fish and Wildlife Service also requires a declaration be filed when fish are brought into the United States.

NOAA Fisheries (National Marine Fisheries Service)

The National Marine Fisheries Service requires no permit.

Mexican Agencies

Mexican regulatory agencies will require fishing licenses and compliance with harvest limits and method of fishing requirements during collection of individuals for transport. There may be additional export restrictions and permit requirements for transporting live fish out of the country.

Other Considerations

Because of rapidly changing conditions in the Salton Sea, the stocks of orangemouth corvina, sargo, and Gulf croaker in the Salton Sea have been subjected to selective pressures that might have produced adaptations that that make those stocks more suitable to conditions in the Salton Sea. To preserve these characteristics, consideration should be given to obtaining individuals of the target species from the Salton Sea if they again reach detectable numbers. These fish could serve as brood stock for a captive rearing program or as genetic representatives of the original population.

APPENDIX A

Salinity Tolerance of Selected Species Potentially Suitable for Introduction to the Salton Sea: An Annotated Bibliography

APPENDIX A: SALINITY TOLERANCE OF SELECTED SPECIES POTENTIALLY SUITABLE FOR INTRODUCTION TO THE SALTON SEA: AN ANNOTATED BIBLIOGRAPHY

The following bibliography is organized by references relevant to salinity tolerance of an individual species, followed by references that include multiple species, and finally general references. The general format is the complete citation (in bold type), followed by an "abstract" or summary of the publication. The information presented as "abstracts" was obtained from the abstracts submitted with the original publications, previous summaries of available documents (e.g. bibliographies compiled for the Salton Sea Authority), or summarized from the publications by the authors of this report. Many citations are included without an annotation or abstract because the title of the publication suggests that it may be relevant, but a copy of the publication was not readily available.

Citations with an available annotation are listed before those that were not annotated.

TILAPIA (*Tilapia* spp.)

Available References

Al-Amoudi, M.M. 1987. Acclimation of commercially cultured *Oreochromis* species to sea water — an experimental study. Aquaculture 65(3-4): 333-342.

An experimental study was conducted on the acclimation of fresh water *Oreochromis* species to sea water in order to evaluate the possible marine culture of the species in the subtropical Red Sea waters of Saudi Arabia. Although *O. aureus*, *O. mossambicus*, *O. spilurus*, *O. niloticus* and *O. aureus*/*O. niloticus* hybrids withstand direct transfer to 18‰ salinity, the species exhibit different mortality rates when transferred directly to higher salinities (>21.6‰). The salinity range of 23.4‰ to 30.6‰ is the critical tolerance level for all the fish. Pre-acclimation to salt water and gradual transfer to higher salinities produced better survival rates.

Al-Amoudi, M.M. 1987. The effect of high salt diet on the direct transfer of *Oreochromis mossambicus*, *O. spilurus* and *O. aureus*/*O. niloticus* hybrids to sea water. Aquaculture 64(4): 333-338.

The effect of feeding a high salt diet on the survival rates of some fresh water *Oreochromis* (formerly *Sarotherodon*) species in marine culture was experimentally investigated. High salt diet (10 percent NaCl) was fed to *O. mossambicus*, *O. spilurus* and *O. aureus*/*O. niloticus* hybrids for a period of 4 weeks and the survival rates were estimated after each week by directly transferring the species to various salinity levels. Feeding of dietary sodium chloride considerably enhanced the survival rates of *O. mossambicus* up to 84 percent, and the *O. aureus*/*O. niloticus* hybrids and *O. spilurus* up to 62 percent and 50 percent, respectively, in sea water. Best survival rates were recorded after 2 weeks of feeding the salt diet for *O. mossambicus* and *O. aureus*/*O. niloticus* hybrids, whereas in *O. spilurus* best survival was not achieved until 3 weeks. Contrary to the sudden increase in plasma osmotic concentration recorded in the fish transferred directly from fresh water to 60 percent sea water, high salt diet feeding prior to the transfer resulted in only a slight increase in the plasma osmotic concentration in sea water.

Chervinski, J. and E. Hering. 1973. *Tilapia zillii* (Gervais) (Pisces, Cichlidae) and its adaptability to various saline conditions. Aquaculture 2: 23-29.

Laboratory experiments were conducted to determine the adaptability of *Tilapia zillii* (Gervais) to various salt concentrations. It was found that the maximum salinity tolerance of *T. zillii*, on direct transfer, is between 60 and 70 percent sea water (S = 23.4 to 27.3‰). Through gradual adaptation the fish can withstand up to 100 percent sea water.

Davis, P., B. Sardella, J. Cooper, R. Gonzalez, C.J. Brauner. 2003. Salinity tolerance of juvenile red bellied tilapia during direct and gradual transfer to elevated salinity. Proceedings of the WDAFS and Cal-Neva Annual Meeting in San Diego. April 14-17, 2003. Downloaded from http://www.wdafs.org/meet/2003/abstracts_Wed2.htm

Approximately 300 *Tilapia zillii* (4 to 10 g) were captured from drainage ditches in traps baited with cat food and transported back to San Diego State University. Fish were then gradually transferred (every 7 days) to progressively increasing salinities of 10, 20, 30, 40 and 50g/L to assess salinity tolerance as indicated by mortality and sublethal indicators such as plasma osmolality, Na+ and Cl- concentrations and muscle water content. No mortality was observed over the duration of this study. A second series of experiments was conducted to determine the threshold of these fish for direct transfer to saline waters.

Green, B.W. 1997. Inclusion of tilapia as a diversification strategy for penaeid shrimp culture. Pages 84-93 in D.E. Alston, B. W. Green, and H. C. Clifford, editors, IV Symposium on

Aquaculture in Central America : Focusing on shrimp and tilapia, 22-24 April 1997, Tegucigalpa, Honduras. Associacion Nacional de Acuacultores de Honduras and the Latin American Chapter of the World Aquaculture Society.

The potential for tilapia culture in brackish water shrimp ponds is evaluated. Nile and blue tilapia can tolerate salinities as high as 36‰ to 40‰, but best growth occurs at salinities below 20‰. Red tilapia, either from Florida or Taiwan, survive and grow well in salinities of 36‰. Mozambique tilapia is able to tolerate salinities as high as 120‰, but good growth is reported through salinities of 36‰. While these tilapia can spawn in waters of various salinities, greater fingerling production is achieved in freshwater or slightly saline (2‰ to 5‰) waters. Maximum salinity tolerance in tilapia appears to be reached at a total length of 50 to 70 mm. Acclimation of tilapia from freshwater to saline water appears best accomplished by increasing salinity from 2.5-5‰ daily until the desired salinity is reached, although some species acclimate more rapidly.

Jurss, K., T. Bittorf, T. Vockler, etal. 1984. Biochemical investigations into the influence of environmental salinity on starvation of the tilapia, Oreochromis mossambicus. Aquaculture 40:171-182.

Tilapias held in fresh water, diluted sea water (10‰) and sea water (33‰) were starved or fed on trout pellets. In terms of live weight losses, the effects of starvation were the same for the fish under all three salinity conditions, but the growth rate of the fed fish in fresh water was lower than in 10‰ or 33‰. Food deprivation makes it more difficult for tilapias to adapt to a saline environment and will increase the negative effects of handling when the fishes are farmed in sea water.

Kultz, D., K. Jurss, and L. Jonas. 1995. Cellular and epithelial adjustments to altered salinity in the gill and opercular epithelium of a cichlid fish (Oreochromis mossambicus). Cell Tiss. Res. 279: 65-73.

Morphological features of the gill and opercular epithelia of tilapia (*Oreochromis mossambicus*) have been compared in fish acclimated to either fresh water (FW) or hypersaline water (60‰) by scanning electron and fluorescence microscopy. In FW-acclimated tilapia, only those mitochondria-rich (MR) cells present on the filament epithelium of the gill were exposed to the external medium. After acclimation of fish to hypersaline water these cells become more numerous, hypertrophy extensively, and form apical crypts not only in the gill filament but also in the opercular epithelium.

Lee, Woo-Jai. 2003. Detection of QTL for salinity tolerance of tilapia. GenoMar ASA, Oslo Research Park, Gaustadallen 21, Oslo 0349 Norway http://www.intl-pag.org/11/abstracts/W05_W24_XI.html

Salinity tolerance is one of the commercially important traits for the fresh water fish in order to expand the farming capability into the sea. Mapping of genes responsible for the salinity tolerance of tilapia has been performed. To determine genomic regions affecting salt tolerance, we developed a pure *O. niliticus* F2 full sib family. A total of 398 F2 were produced, of which 298 F2 were used for mapping the salinity QTLs. These experiments were carried out in the GIFT station in the Philippines by increasing salinity 4ppt per hour. The mortality started from 27ppt and the maximum salinity challenged was 40 ppt. All fish were genotyped with microsatellite and SNP markers at every 20 cM across the whole genome. Quantitative trait loci were detected and characterized by a multiple regression analysis. We detected two QTL regions with LOD score of 5.2 and 18.7 respectively in two different chromosomes. To confirm the effects of QTL, first, the associated markers will be tested out against a brood stock specially designed for farming in salt water and, if necessary, more detailed mapping will be done with a F3 family derived from the F2 family used for the current study, together with an effort mapping genes differentially expressed between salt and fresh water environments.

Likongwe, J.S., T.D. Stecko, J.R. Stauffer, Jr. and R.F. Carline. 1996. Combined effects of water temperature and salinity on growth and feed utilization of juvenile Nile tilapia Oreochromis niloticus (Linneaus). Aquaculture 146(1-2): 37-46.

Juvenile Nile tilapia, *Oreochromis niloticus* (Linneaus) (average weight 4.60 to 4.83 g) were raised in 75-liter glass tanks at a stocking density of 15 fish per tank and fed a 50 percent protein diet for 56 days. Combined effects of temperature (24, 28, and 32 °C) and salinity (0, 8, 12, and 16 g/l) on growth and feed utilization under a 12L:12D photoperiod were studied. Significant ($P < 0.05$) effects of temperature, salinity, and their interaction on growth were observed. Final mean weights were significantly ($P < 0.05$) higher at 32 and 28 °C than 24 °C at 12 g/l salinity, where fish increased their weights seven-fold and four-fold, respectively. Feed conversion efficiencies and protein efficiency ratios were highest at 32 °C and 8 g/l salinity, and lowest at 28 °C and 16 g/l salinity. At all salinities, growth increased with temperature, but at all temperatures an increase in salinity generally inhibited growth. At 32 °C and 16 g/l salinity, fish developed body lesions. The study suggested that growth rates of juvenile *O. niloticus* may be comparably high at 28 or 32 °C in waters of 0 and 8 g/l salinity.

Lin, Li-Yih, Ching-Feng Weng, and Pung-Pung Hwang. 2000. Effects of Cortisol and Salinity Challenge on Water Balance in Developing Larvae of Tilapia (Oreochromis mossambicus). Physiol. Biochem. Zool. 73:283-289.

Effects of exogenous cortisol on drinking rate and water content in developing larvae of tilapia (*Oreochromis mossambicus*) were examined. Both freshwater- and seawater-adapted larvae showed increases in drinking rates with development. Drinking rates of seawater-adapted larvae were about four- to ninefold higher than those of freshwater-adapted larvae from day 2 to day 5 after hatching. Seawater-adapted larvae showed declines in drinking rate and water content at 4 and 14 hours, respectively, after immersion in 10 mg/L cortisol. In the case of freshwater-adapted larvae, the drinking rate decreased after 8 h of cortisol immersion, while the water content did not show a significant change even after 32 hours of cortisol immersion. In a subsequent experiment of transfer from freshwater to 20 ppt (parts per thousand, salinity) seawater, immersion in 10 mg/ L cortisol for 8 to 24 hours enhanced the drinking rate in larvae at 4 hours after transfer, but no significant difference was found in water contents between cortisol-treated and control groups following transfer. These results suggest that cortisol is involved in the regulation of drinking activity in developing tilapia larvae.

Lin, Li-Yih, Ching-Feng Weng, and Pung-Pung Hwang. 2001. Regulation of Drinking Rate in Euryhaline Tilapia Larvae (Oreochromis mossambicus) during Salinity Challenges. Physiol. Biochem. Zool. 74:171-177.

In this study, the water balance of developing tilapia larvae (*Oreochromis mossambicus*) adapted to freshwater (FW) or seawater (SW) was compared, and the short-term regulation of drinking rate of the larvae during salinity adaptation was also examined. Following development, wet weight and water content of both SW- and FW-adapted larvae increased gradually, while the dry weight of both groups of larvae showed a slow but significant decline. On the other hand, the drinking rate of SW-adapted larvae was four to nine-fold higher than that of FW-adapted larvae from day 2 to day 5 after hatching. During acute salinity challenges, tilapia larvae reacted profoundly in drinking rate, that is, increased or decreased drinking rate within several hours while facing hypertonic or hypotonic challenges, to maintain their constancy of body fluid. This rapid regulation in water balance upon salinity challenges may be critical for the development and survival of developing larvae.

Lin, Li-Yih and Pung-Pung Hwang. 2001. Modification of Morphology and Function of Integument Mitochondria-Rich Cells in Tilapia Larvae (Oreochromis mossambicus) Acclimated to Ambient Chloride Levels. Physiol. Biochem. Zool. 74:469-476.

The object of this study is to test the hypothesis that three types of mitochondria-rich (MR) cells may represent MR cells equipped with variable efficiencies in Cl^- uptake. Larvae acclimated to low-Cl^- ([Cl^-] = 0.001 to 0.007 mM) water developed higher densities of MR cells than those acclimated to high-Cl^- ([Cl^-] = 7.3 to 7.9 mM) water. The percentage of wavy-convex-type cells in total MR cells was higher in low-Cl—acclimated larvae than in high-Cl—acclimated larvae, which displayed only deep-hole type. In addition, Cl^- influx rates of whole larva measured with $^{36}Cl^-$ showed a coincident correlation with MR cell densities, that is, low-Cl^- larvae displayed higher Cl^- influx rates than did high-Cl^- larva, suggesting that tilapia larvae develop a higher density of MR cells with larger apical surfaces (wavy-convex type) to boost Cl^- uptake in Cl—deficient water. The distinct types of apical surfaces may represent different phases of MR cells that possess different efficiencies of Cl^- uptake. Increased apical membrane surface areas of MR cells may provide larvae with rapid regulation of Cl^- before new MR cells differentiate.

Nugon, R.W. 2003. Salinity tolerance of juveniles of four varieties of tilapia. Masters Thesis, Louisiana State University. Baton Rouge, Louisiana.

Juvenile (4 g) tilapia of four varieties, Nile tilapia (*Oreochromis niloticus*), blue tilapia (*O. aureus*), Florida red tilapia (*O. urolepis hornorum* x *O. mossambicus*), and Mississippi commercial tilapia (*Oreochromis* spp.) were tested for salinity tolerance. This was accomplished by subjecting them to four salinity regimes during a 97-h period with as long as 63 h acclimation. Salinity regimes represented salinities found along coastal Louisiana. Each variety was challenged individually against every other variety and thus in triplicate. The Florida red tilapia and Mississippi commercial tilapia are hybrid-based varieties (distinct species were crossed to produce their lineages). Juvenile *O. aureus*, *O. niloticus*, and Florida red tilapia exhibited good survival (> 81 percent) in salinity regimes up to 20 ppt, with moderate survival of *O. aureus* (54 percent) and Florida red tilapia (33 percent) at 35 ppt salinity. Mississippi commercial tilapia survived salinity regimes up to 10 ppt and exhibited poor survival at 20 ppt (5 percent).

Payne, A.I. and R.I. Collinson. 1983. A comparison of the biological characteristics of Sarotherodon niloticus (L.) with those of S. aureus (Steindachner) and other tilapia of the delta and lower Nile. Aquaculture 30: 335-351.

A number of biological characteristics of tilapia species were compared. With respect to salinity tolerance, the salinity tolerance of the Nile tilapia can be ranked as *T. zillii* > *S. galilaeus* > *S. aureus* > *S. niloticus*. Evidence on chronic and acute effects of salinity are reviewed and upper estimates for salinities giving unimpeded growth are deduced as being, *T. zillii* 29‰, *S. galilaeus* 15 to 20‰, *S. areus* 10 to 15‰ and *S. niloticus* 5 to 10‰.

Popper, D. and T. Lichatowich. 1975. Preliminary success in predator contact of Tilapia mossambica. Aquaculture 5:213-214.

In this short communication, the results of some preliminary experiments are presented which indicate that the population of *Tilapia mossambica* in seawater ponds might be controlled by allowing unlimited numbers of *Elops hawaiiensis* into the ponds.

Sardella, B.A., J. Cooper, R.J. Gonzalez and C.J. Brauner. 2004. The effect of temperature on juvenile Mozambique tilapia hybrids (Oreochromis mossambicus x O. urolepis hornorum) exposed to full-strength and hypersaline seawater. Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology, 137(4): 621-629.

The effects of temperature on the salinity tolerance of Mozambique–Wami tilapia hybrids (*Oreochromis mossambicus* x *O. urolepis hornorum*) were investigated by transferring 35 g/l, 25 °C-acclimated fish to

35, 43, 51 or 60 g/l salinity at 15, 25 or 35 °C for 24 hours, and by assaying gill tissue for branchial Na^+, K^+-ATPase activity at the three temperatures after acclimating the fish to 15, 25 or 35 °C for 2 weeks. Tilapia survived all salinities at 25 and 35 °C; however, at 15 °C, mortality was 85.7 percent and 100 percent in the 51 g/l and 60 g/l groups, respectively. There was a significant interaction between temperature and salinity, as plasma osmolality, $[Na^+]$ and $[Cl^-]$ were significantly increased at 51 and 60 g/l salinity in 35 °C water ($P<0.001$). Additionally, muscle water content was significantly reduced at 43 g/l, 15 °C relative to pre-transfer values ($P<0.001$). Branchial Na^+, K^+-ATPase activity was reduced at 15 °C regardless of acclimation temperature, and 25 °C-acclimated gill tissue did not show an increase in activity when assayed at 35 °C. Results indicate that the effects of a combined temperature–salinity transfer on plasma osmolality and ion concentrations, as well as muscle water content, are greater than when either challenge is given alone.

Sardella, B., V. Matey, J. Cooper, R.J. Gonzalez, and C.J. Brauner. 2004. Mechanisms of salinity tolerance in California Mozambique tilapia (Oreochromis mossambicus x O. urolepis hornorum) exposed to salinities greater than seawater. IN Steve McCormick Don MacKinlay (eds.). Ion and Acid-Base Regulation in Fish. Symposium Proceedings, International Congress on the Biology of Fish. Tropical Hotel Resort, Manaus Brazil, August 1-5, 2004

The salinity tolerance of the California Mozambique tilapia, a current resident of the hypersaline Salton Sea in southeastern California, was investigated by gradually acclimating fish to progressively increasing salinities from 35 to 95 g/l (in 10 g/l increments for five days per increment), while physiological, biochemical, and morphological indicators of osmoregulatory stress were measured. Tilapia survived exposure to all salinities with only minor mortality in the 85 g/l treatment. Our results indicate that tilapia maintain internal osmotic balance without any change in drinking rate or branchial Na^+, K^+-ATPase activity when exposed to salinities up to 65 g/l for five days. At 65 g/l salinity or greater, there were changes in chloride cell turnover, drinking rate, and Na^+, K^+-ATPase activity; followed by increases in plasma osmolality and ion levels. We conclude that this tilapia hybrid maintains its internal environment by decreasing its epithelial permeability, perhaps as an acute measure for dealing with short term increases in environmental salinity, but when ambient salinity is too great, strategies of osmoregulation such as increased drinking rate and increased branchial Na^+, K^+-ATPase activity become apparent. Further investigation may also determine if the duration of exposure plays a role in osmoregulatory strategy.

Sardella, B.A., V. Matey, J. Cooper, R.J. Gonzalez, and C.J. Brauner. 2004. Physiological, biochemical and morphological indicators of osmoregulatory stress in California Mozambique tilapia (Oreochromis mossambicus x O. urolepis hornorum) exposed to hypersaline water. J. Exp. Biol. 207: 1399-1413.

The salinity tolerance of the California Mozambique tilapia (Oreochromis mossambicus x O. urolepis hornorum), a current inhabitant of the hypersaline Salton Sea in California, USA, was investigated to identify osmoregulatory stress indicators for possible use in developing a model of salinity tolerance. Seawater-acclimated (35 g/l) tilapia hybrids were exposed to salinities from 35 to 95 g/l, using gradual and direct transfer protocols, and physiological (plasma osmolality, [Na+], [Cl–], oxygen consumption, drinking rate, hematocrit, mean cell hemoglobin concentration, and muscle water content), biochemical (Na+, K+-ATPase) and morphological (number of mature, accessory, immature and apoptotic chloride cells) indicators of osmoregulatory stress were measured. Tilapia tolerated salinities ranging from 35 g/l to 65 g/l with little or no change in osmoregulatory status; however, in fish exposed to 75 to 95 g/l salinity, plasma osmolality, [Na+], [Cl–], Na+, K+-ATPase, and the number of apoptotic chloride cells, all showed increases. The increase in apoptotic chloride cells at salinities greater than 55 g/l, prior to changes in physiological and biochemical parameters, indicates that it may be the most sensitive indicator of osmoregulatory stress. Oxygen consumption decreased with salinity, indicating a reduction in activity level at high salinity. Finally, California Mozambique tilapia have a salinity tolerance similar to that of pure Mozambique tilapia; however, cellular necrosis at 95 g/l indicates they may be unable to withstand extreme salinities for extended periods of time.

Stickney R.R. 1986. Tilapia tolerance of saline waters: a review. Prog. Fish. Cult. 48: 161-167.

A survey of existing literature indicates that *Tilapia zilli* and *Tilapia mossambica* are among the most salinity-tolerant species, although neither is among the most desirable for culture. A tolerance for high salinity has been demonstrated in at least some crosses that produce red hybrid tilapia. Most known heritage crosses with that result to date have involved *T. mossambica*. The red hybrid may become a preferred culture fish in brackish and seawater systems as well as in fresh water.

Suresh, A.V. and C.K. Lin. 1992. Tilapia culture in saline waters: a review. Aquaculture 106:201-226.

This review attempts to evaluate the potential of tilapia culture in saline waters and in the process employs biological, economic and environmental considerations in the analytical framework. Tilapia tolerate, grow and even reproduce in saline waters, although this capacity is somewhat offset under high salinity conditions. Particularly they are sensitive to handling and succumb to secondary infections in seawater salinities. A range of 10 to 20 ppt is optimal for growth. Optimal dietary protein content is 20 to 25 percent and feeding rates close to satiation levels lead to the highest growth.

Uchida, K., T. Kaneko, and H. Miyazaki. 2000. Excellent salinity tolerance of Mozambique tilapia (Oreochromis mossambicus): elevated chloride cell activity in the branchial and opercular epithelia of the fish adapted to concentrated seawater. Zoological Science, Vol.17, pp.149-160.

Changes in morphology and cellular activity of the chloride cells in branchial and opercular epithelia were examined in tilapia, *Oreochromis mossambicus*, adapted to fresh water(FW), seawater(SW)and concentrated SW(180 percent SW). Tilapia are adaptable to a wide range of salinity, maintaining the plasma osmolality within physiological levels. Gill Na^+, K^+-ATPase activity was remarkably increased in response to elevated environmental salinity. The size of immunoreactive chloride cells was twice as large in SW and four times larger in 180 percent SW than in FW. These findings suggest that highly activated chloride cells in branchial and opercular epithelia may be responsible for salt secretion in hyperosmotic environments. The excellent salinity tolerance of tilapia appears to be attributed to their ability to develop chloride cells in response to increased environmental salinity.

Verdegem, M.C.J., A.D. Hilbrands, and J.H. Boon. 1997. Influence of salinity and dietary composition on blood parameter values of hybrid red tilapia, Oreochromis niloticus (Linnaeus) x O. mossambicus (Peters). Aquaculture Research, v. 28, p. 453-459.

The influence of salinity and dietary composition on blood parameter values (haematocrit, leucocrit, immature lymphocytes, mature lymphocytes, granulocytes, plasma osmolarity and total plasma protein) of red hybrid tilapia, *Oreochromis niloticus* (Linnaeus) ×*O. mossambicus* (Peters), was studied. Two groups of tilapia were fed a high-protein diet while kept in fresh or brackish water, respectively, and compared with two groups fed a low-protein diet under similar environmental conditions. Treatments were executed in duplo. Results show that salinity influenced all cellular blood parameters except the haematocrit. Dietary composition influenced the total plasma protein and haematocrit, while all parameters changed as time progressed during the experiment. It was concluded that the environmental parameters investigated in the present study should be considered when estimating fish health based on blood parameter values.

Vijayan, M., J. Morgan, T. Sakamoto, E. Grau, and G. Iwama. 1996. Food-deprivation affects seawater acclimation in tilapia: hormonal and metabolic changes. J. Exp. Biol. 199: 2467-2475.

We tested the hypothesis that nutritional state affects seawater acclimation by transferring either fed or food-deprived (2 weeks) male tilapia (*Oreochromis mossambicus*) from fresh water to full-strength sea water. The results indicate that food-deprived fish did not regulate their plasma Cl- levels, despite an enhancement of plasma hormonal and metabolic responses in sea water. Our study also suggests the possibility that plasma prolactin and essential amino acids may be playing an important role in the seawater acclimation process in tilapia.

Villegas, C.T. 1990. Evaluation of the salinity tolerance of Oreochromis mossambicus, O. niloticus and their F1 hybrids. Aquaculture 85: 281-292.

The salinity tolerance of freshwater-spawned and reared *Oreochromis mossambicus*, *O. niloticus* and their F_1 hybrids of various ages was studied. Several tests were conducted using three indices as practical measures of salinity tolerance: (1) mean survival time (MST); (2) median survival time (ST_{50}); and (3) median lethal salinity-96 hours (MLS-96).

Interspecific and age-specific differences ($P<0.01$) in salinity tolerance were observed in these species and their F_1 hybrids on the basis of MST and ST_{50} indices, with salinity tolerance generally increasing with age of brood. No significant age-specific differences ($P > 0.05$) in salinity tolerance were observed in all four groups on the basis of MLS-96 index. At the same salinity *O. niloticus* fry at ages from 15 to 90 days post-hatch exhibited significantly lower ($P<0.05$) salinity tolerance than *O. mossambicus* and F_1 hybrids. Changes in salinity tolerance were determined to be more closely related to body size than age.

Wahby, S.D., and F. Bishara. 1977. Physical and chemical factors affecting fish distribution in Lake Manzalah—Egypt. Acta Ichthyol. Piscat. 7(1): 15-30.

The fish distribution in Lake Manzalah, the largest of the Delta Lakes of Egypt, was studied and discussed in the light of the prevailing physical and chemical conditions. The lake-sea connection is of vital importance for the welfare of the lake and has a pronounced effect on the its distribution. Many marine forms like *Mugil cephalus*, *M. capito*, *Sciaena aquilla*, *Chrysophris aurata*, *Morone labrax*, *M. punctata* and shrimps can tolerate the brackish water of the lake during certain phases of their life. *Tilapia* spp., namely *Tilapia aurea*, *T.galilaea*, *T. nilotica* and *T zillii* being the principal fish in the lake have different degrees of salinity tolerance. The tolerance limits of different ecological factors like salinity, temperature, pH and dissolved oxygen was determined for different species of fish.

Watanabe, W.O., L.J. Ellingson, B.L. Olla, D.H. Ernst and R.I. Wicklund. 1990. Salinity tolerance and seawater survival vary ontogenetically in Florida red tilapia. Aquaculture 87(3-4): 311-321.

Salinity tolerance at 10, 25, 40, 55 and 70 days post-hatching was determined in Florida red tilapia fry spawned at 5 ppt. There was a trend toward increased tolerance with age, with mean survival time following abrupt transfer to 32 ppt increasing from 190 minutes at 10 days post-hatching, to 3,915 minutes at 70 days post-hatching. Ninety-six-hour median lethal salinity increased from 24.8 ppt at 10 days to >32 ppt at 70 days post-hatching. Tolerance improved markedly from 40 days post-hatching. Survival was compared for fish gradually acclimated to seawater (37 ppt) over 7 days, beginning at 11, 25 or 39 days post-hatching. Survival to 48 days post-hatching improved as acclimation to seawater was delayed, from 20.0 percent to 55.9 percent for fish beginning acclimation at 11 and 39 days post-hatching. For fish surviving acclimation to seawater, growth through 105 days post-hatching was not influenced by age at acclimation. The results demonstrated that premature transfer to seawater can impair survival in this fish, and that selection of proper transfer time, based on knowledge of ontogenetic variation in salinity tolerance, can improve survival. Long-term growth in seawater, however, was not influenced by age at transfer.

Watanabe, W.O.; Ernst, D.H.; Chasar, M.P.; Wicklund, R.I.; Olla, B.L. 1993. The effects of temperature and salinity on growth and feed utilization of juvenile, sex-reversed male Florida red tilapia in a recirculating system. Aquaculture 112 (4): 309-320.

In two experiments, juvenile, sex-reversed male Florida red tilapia (avg. wt.=0.56–1.20 g) were stocked into forty-two 0.33-m3 indoor tanks at a density of 74 fish m−3 and growth and feed utilization compared for 54–58 days at temperatures of 22, 27 and 32°C and at salinities of 0 and 18 ppt (experiment one) or at 18 and 36 ppt (experiment two) under a 12 L: 12 D photoperiod. Fish were fed twice daily to satiation a 32 percent protein diet. While growth rates generally increased with increasing temperature and were markedly lower at 22°C than at 27 and 32°C, salinity modified the effects of temperature on growth: at 0 ppt, feed consumption and growth reached a maximum at 27°C, while at 18 and 36 ppt, consumption and growth were highest at 32°C. Under all temperatures, feed consumption and growth were higher at 18 ppt than at 0 or 36 ppt. The results suggested that, in freshwater, heating water to temperatures above 27°C is not justifiable, while at 18 or 36 ppt, heating water to 32°C can maximize growth rates without lowering growth efficiency.

Watanabe, Wade O. and Ching-Ming Kuo. 1985. Observations on the reproductive performance of Nile tilapia (Oreochromis niloticus) in laboratory aquaria at various salinities. Aquaculture 49 (3-4): 315-323.

The reproductive performance of yearling *Oreochromis niloticus* broodstock was monitored under laboratory conditions at various salinities and results compared with the performance of an older (2- to 3-year) broodstock in freshwater. Spawning was observed in salinities ranging from freshwater to full seawater (32 ppt). Extremely poor hatching success was obtained with eggs spawned in full seawater. Mean hatching successes were similar for eggs spawned by yearling females in freshwater (30.9 percent), 10 ppt (32.7 percent) and 15 ppt (36.9 percent). Mean hatching success was considerably higher for eggs spawned at 5 ppt (51.6 percent) compared to that obtained with eggs spawned by older females in freshwater (54.2 percent). Egg and fry production per female was much greater in the older broodstock in freshwater than in yearling females in water of any salinity. Egg and fry production per unit weight was greater in yearling females in salinities of 5 to 15 ppt than in older females in freshwater.

Watanabe, W.O.; Kuo, C.M.; Huang, M.C. (1984). Experimental rearing of Nile tilapia fry (Oreochromis niloticus) for saltwater culture. ICLARM Tech. Rep. (14): 28 p. Taiwan. Council for Agricultural Planning and Development; Published jointly by the Council for Agricultural Planning and Development, Taipei, Taiwan and ICLARM.

Represents a preliminary evaluation of the utility of various approaches of early salinity exposure for saltwater culture of tilapias. Studies the reproductive performance of Nile tilapia under laboratory conditions at various salinities; salinity tolerance of progeny; survivorship of fertilized eggs, spawned in freshwater but removed from the mouth of the parent female and artificially incubated at various salinities.

Watanabe, Wade O., Ching-Ming Kuo and Mei-Chan Huang. 1985. Salinity tolerance of Nile tilapia fry (Oreochromis niloticus), spawned and hatched at various salinities. Aquaculture 48(2): 159-176.

Fertilized eggs of the Nile tilapia (*Oreochromis niloticus* L.) spawned in freshwater, were removed from mouthbrooding females, 1 day post-spawning and artificially incubated at elevated salinities. At 6 days post-hatching, mean survivals of 85.5, 84.4, 82.5, 56.3, 37.9, 20.0 and 0 percent were recorded for broods incubated at salinities of 0, 5, 10, 15, 20, 25 and 32 ppt, respectively. Fertilized eggs exhibited a 96-hour median lethal salinity (MLS-96) of 18.9 ppt, a value identical to that of 7- to 120-day-old fry and fingerlings. Fertilized eggs exhibited a higher median survival time (ST_{50} = 978 min) than 7- to 395-day-old fry and fingerlings (ST_{50} = 28.8–179.0 min).

The salinity tolerances of fry spawned at various salinities and fry spawned in freshwater but hatched at various salinities, were determined using the median survival time (ST_{50}), mean survival time (MST) and 96 hour-median lethal salinity (MLS-96) indices. For comparative purposes, fry spawned and hatched in freshwater were acclimatized to various salinities and their salinity tolerance determined. Fry salinity tolerance progressively increased with increasing salinity of spawning, hatching, or acclimatization. However, at equivalent salinity, early exposure (spawning) produced progeny of comparatively higher salinity tolerance than those spawned in freshwater and hatched at elevated salinity. Similarly, at equivalent salinity, progeny spawned in freshwater but hatched at elevated salinity exhibited higher salinity tolerance than those spawned and hatched in freshwater, then acclimatized to an elevated salinity.

Watanabe, W.O.; C.M. Kuo, and M.C. Huang. 1985. Salinity tolerance of the tilapias Oreochromis aureus, O. niloticus and an O. mossambicus X O. niloticus hybrid. ICLARM Tech. Rep. (16): 22 p.

Studies ontogenetic changes in salinity tolerance in tilapias spawned and reared in freshwater using the indices of median lethal salinity, mean survival time and median survival time. Discusses implications of findings for brackish- and seawater culture of tilapias.

Watanabe, Wade O., Ching-Ming Kuo and Mei-Chan Huang. 1985. The ontogeny of salinity tolerance in the tilapias Oreochromis aureus, O. niloticus, and an O. mossambicus x O. niloticus hybrid, spawned and reared in freshwater. Aquaculture 47(3): 353-367.

The ontogeny of salinity tolerance was studied in the tilapias *Oreochromis aureus*, *O. niloticus*, and an *O. mossambicus* (♀) × *O. niloticus* (♂) (M × N) hybrid, spawned and reared in freshwater. Several indices were used as practical measures of salinity tolerance: (1) Median Lethal Salinity — 96 hour (MLS-96), defined as the salinity at which survival falls to 50 percent, 96 hour following direct transfer from freshwater to various salinities; (2) Mean Survival Time (MST), defined as the mean survival time over a 96 hour period, following direct transfer from freshwater to full seawater (32‰); and (3) Median Survival Time (ST_{50}), defined as the time at which survival falls to 50 percent following direct transfer from freshwater to full seawater.

No significant age-specific differences in salinity tolerance were observed in either *O. aureus* or *O. niloticus* on the basis of the MLS-96 index. In contrast, the M × N hybrid exhibited relatively greater changes in salinity tolerance with age. Distinct age-specific differences in salinity tolerance were observed in all three on the basis of the MTS and ST_{50} indices. These ontogenetic changes in salinity tolerance were determined to be more closely related to body size than to chronological age. No consistent relationship was observed between salinity tolerance and condition factor.

Weng, Ching-Feng, Chia-Chang Chiang, Hong-Yi Gong, Mark Hung-Chih Chen, Cliff Ji-Fan Lin, Wei-Tung Huang, Ching-Yi Cheng, Pung-Pung Hwang, and Jen-Leih Wu. 2002. Acute Changes in Gill Na+-K+-ATPase and Creatine Kinase in Response to Salinity Changes in the Euryhaline Teleost, Tilapia (Oreochromis mossambicus). Physiological and Biochemical Zoology 75(1):29-36.

This study was conducted to examine the changes in expression of gill Na^+-K^+-ATPase and creatine kinase (CK) in tilapia (*Oreochromis mossambicus*) as the acute responses to transfer from freshwater (FW) to seawater (SW). After 24 hours in 25 ppt SW, gill Na^+-K^+-ATPase activities were higher than those of fish in FW. Fish in 35 ppt SW did not increase gill Na^+-K^+-ATPase activities until 1.5 hours after transfer, and then the activities were not significantly different from those of fish in 25 ppt SW. Compared to FW, the gill CK activities in 35 ppt SW declined within 1.5 hours and afterward dramatically elevated at 2 hours, as in 25 ppt SW, but the levels in 35 ppt SW were lower than those in 25 ppt SW. The Western blot of muscle-type CK (MM form) was in high association with the salinity change, showing a pattern of changes similar to that in CK activity; however, levels in 35 ppt SW were higher than those in 25 ppt SW. The activity of Na^+-K^+-

ATPase highly correlated with that of CK in fish gill after transfer from FW to SW, suggesting that phosphocreatine acts as an energy source to meet the osmoregulatory demand during acute transfer.

Yada, T., T. Hirano and E. Gordon Grau. 1994. Changes in Plasma Levels of the Two Prolactins and Growth Hormone during Adaptation to Different Salinities in the Euryhaline Tilapia, Oreochromis mossambicus. General and Comparative Endocrinology, 93 (2): 214-223.

Studies were undertaken to determine whether the adaptation of the tilapia. *Oreochromis mossambicus*, to different salinities was accompanied by changes in plasma levels of growth hormone (GH) and its two prolactins ($tPRL_{177}$ and $tPRL_{188}$). Transfer from fresh water to 70 percent seawater (22 ppt) produced significant increases in plasma GH levels in males, but not in females. Both tPRLs decreased by the first sampling interval (6 hour) after transfer to seawater in both sexes. A second group of tilapia were adapted gradually to seawater (32 ppt) and were maintained in seawater for an additional 2 weeks. The fish were then transferred from seawater to fresh water. The transfer to fresh water induced a significant decline in plasma GH levels in both males and females. Both tPRLs increased within 6 hr after transfer to fresh water in both sexes. Then, plasma $tPRL_{177}$ levels decreased gradually. By contrast, $tPRL_{188}$ continued to increase and attained its highest levels 3 days after transfer to fresh water. These findings show that blood levels of the two tPRLs change rapidly during freshwater and seawater adaptation. The fact that $tPRL_{177}$ and $tPRL_{188}$ levels followed distinctly dissimilar patterns as freshwater acclimation proceeded suggests that the secretion and/or metabolic clearance of the two PRLs may be differentially regulated. The changes in GH which occurred when tilapia were moved between fresh water and seawater are compatible with the idea proposed by others for salmonids that GH may have an important role for seawater adaptation.

Zale, A. and R.W. Gregory. 1989: Effect of Salinity on Cold Tolerance of Juvenile Blue Tilapias. Transactions of the American Fisheries Society: Vol. 118, No. 6, pp. 718–720.

Cold tolerances of juvenile blue tilapias *Oreochromis aureus* at salinities ranging from 0 to 35‰ were determined in the laboratory by decreasing temperatures 1°C/day until fish died. Fish maintained in isosmotic media (11.6‰) survived at lower temperatures than those in water of higher or lower salinity. Therefore, the potential range of this exotic species in North America can be expected to extend farthest north in estuarine habitats. Inasmuch as the difference in thermal tolerance between blue tilapias in fresh water and those in isosmotic media was small, (about 1°C) the additional habitable range may also be relatively small.

Zdanovich, V.V. (1999). Some features of growth of the young of Mozambique tilapia, Oreochromis mossambicus, at constant and fluctuating temperatures. J.Ichthyol. 39 (1): 100-104.

The growth rate of the young of Mozambique tilapia, *Oreochromis mossambicus*, is studied at constant and fluctuating temperatures. Under oscillating temperatures within the ecological tolerance range for the species, the growth rate increases compared to the growth rate in the control groups with a constant temperature equal to the average oscillating one. The maximum positive influence of fluctuating temperature on the growth rate is observed in a thermogradient field with parameters related to thermopreference behavior of fish.

Other Citations

Al Amoudi, M., A.F. El-Sayed and A. El-Ghobashy. 1996. Effects of thermal and thermo-haline shocks on survival and osmotic concentration of the tilapias *Oreochromis mossambicus* and *Oreochromis aureus* x *Oreochromis niloticus* hybrids. J. World Aqua. Soc. 27:456–461.

Allanson, B.R., A. Bok, and N.I. van Wyk. 1971. The influence of exposure to low temperatures on *Tilapia mossambica* Peters (Cichlidae). II. Changes in serum osmolarity, sodium and chloride ion concentrations. Journal of Fish Biology 3:181-185.

Avella, M., J. Berhaut, M. Bornancin. 1993. Salinity tolerance of two tropical fishes, *Oreochromis aureus* and *O. niloticus*. I. Biochemical and morphological changes in the gill epithelium: Journal of Fish Biology, v. 42, p. 243-254.

Avella, M. and T. Doudet. 1996. Physiological adaptation of *Oreochromis niloticus* and *O. aureus* to salinity, in RSV Pullin, J Lazard, M Legendre, JBA Kothias, and D Pauly (eds), Manila, Philippines., International Center for Living Aquatic Resorces Management (ICLARM), Centre de recherches océanologiques (CRO), Institut francais de recherches scientifique pour le développment en coopération (ORSTOM), Centre de coopération internationale en recherche agronomique pour le developpment/ Départment d'élevage et de médecine vétérinaire (CIRAD-EMVT), p. 461-470.

Bruton, M.N., and M. Gophen. 1992. The effect of environmental factors on the nesting and courtship behaviour of *Tilapia zilli* in Lake Kinneret (Isreal). Hydrobiologia 239:171-178.

Chang, H.J. 1986. Determination of salinity tolerance of Tilapia hybrids. Bull. Taiwan Fish. Res. Inst. 41: 219-231.

Chang, H.Y. and Y.Y. Teng. 1986. Study on the physiological change of Tilapia under various salinities. Bull. Taiwan Fish. Res. Inst. 41: 233-240.

Chang, P.H. and J.A. Plumb. 1996. Effects of salinity on *Streptococcus* infection of Nile tilapia, *Oreochromis niloticus*. J. Appl. Aquacult. 6 (1): 39-45.

Chervinski, J. 1971. Sexual dimorphism in *Tilapia aurea* and *Tilapia zillii* from Dor and from Lake Tiberias. Bamidgeh 23: 56-59.

Chimits, P. 1957. Tilapia in ancient Egypt. FAO Fisheries Bulletin, 10(4):i-5.

Chung, K.S. 1985. Adaptabilidad de *Oreochromis mossambicus* (Peters, 1852) a los cambios de temperature. Acta Cient. Venezolana 36:180-190.

Chung, K.S. 1990. Adaptabilidad de una especie eurihalina *Oreochromis mossambicus* (Peters, 1852) en agues saldaas de la zona nororiental de Venezuela. Saber 3:21-30.

Dange, A.D. 1985. Branchial Na^+/K^+ - ATPaxse activity during osmotic adjustments in two freshwater teleosts, tilapia (*Sarotherodon mossambicus*) and orange chromid (*Etroplus maculates*). Mar. Biol. 87:101-107.

Dange, A.D. 1986. Branchial Na+-K+-ATPase inhibition in a freshwater euryhaline teleost, tilapia (*Oreochromis mossambicus*), during short-term exposure to toluene or naphthalene: influence of salinity. Environmental Pollution 42A:273-86.

De Silva, C.D., S. Premawansa, and C.N. Keembiyahetty. 1986, Oxygen consumption in *Oreochromis niloticus* (L.) in relation to development, salinity, temperature and time of day: Journal of Fish Biology 29: 267-277.

Fineman-Kalio, A.S. 1988. Preliminary observations on the effect of salinity on the reproduction and growth of freshwater Nile tilapia, *Oreochromis niloticus* (L.), cultured in brackishwater ponds. Aquacult. Fish. Manage. 19 (3): 313-320.

Hauzer, W.J. 1977. Temperature requirements of *Tilapia zilli*. California Fish and Game 63(4):228-233.

Hora, S.L. and T.V.R. Pillay, 1962. Handbook of fish culture in the Indo-Pacific region. FAO Fish. Biol. Tech. Pap. 14. 204 p.

Hwang, P.P. 1987. Tolerance and ultrastructural responses of branchial chloride cells to salinity changes in the euryhaline teleost *Oreochromis mossambicus*. Mar. Biol. 94:643-649.

Hwang, P.P., C.M. Sun, and S.M. Wu. 1989. Changes of plasma osmolarity, chloride concentration and gill Na-K-ATPase activity in tilapia *Oreochromis mossambicus* during seawater acclimation. Marine Biology 100:295-299.

Kultz D. and H. Onken. 1993. Long-term acclimation of the teleost *Oreochromis mossambicus* to various salinities: two different strategies in mastering hypertonic stress. Mar. Biol. 117: 527-33

Lahav, E., and Ra´anan, Z., 1997. Salinity tolerance of genetically produced tilapia (*Oreochromis*) hybrids. The Israelí Journal of Aquaculture-Bamidgeh, 49 (3):160-165.

Lee, T.H., P.P. Hwang, H.C. Lin, F.L. Huang. 1996. Mitochondria rich cells in the branchial epithelium of the teleost, *Oreochromis mossambicus*, acclimated to various hypotonic environments. Fish. Physiol. Biochem. 15: 513-523.

Legner, E. and F. Pelsue. 1977. Adaptations of Tilapia to *Culex* and chironomid midge ecosystems in South California. Proc. Ann. Conf. Cal. Mosquito Vector Cont. Assoc. 45: 95-97.

Morgan, J.D., T. Sakamoto, E.G. Grau et al. 1997. Physiological and respiratory responses of the Mozambique tilapia (*Oreochromis mossambicus*) to salinity acclimation. Comp. Biochem. Physiol. 117:391-398.

Morgan, P.R. 1972. Causes of mortality in the endemic Tilapia of Lake Chilwa (Malawi). Hydrobiologia 40: 101-119.

Myers, G. S. 1938. Fresh-water fishes and West Indian zoogeography. Ann. Rept. Smithsonian Inst. for 1937, pp. 339-364.

Payne, A.L., J. Ridgway, and J.L. Hamer. 1988. The influence of salt (NaCl) concentration and temperature on the growth of *Oreochromis spilurus spilurus*, *O. mossambicus* and a red tilapia hybrid. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. Maclean (Editors), The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings No. 15, Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines, pp. 481–487.

Perschbacher, P.W. and R.B. McGeachin. 1988. Salinity tolerance of red hybrid tilapia fry, juveniles and adults. ICLARM Conf. Proc. (15): 415-419.

Philippart, J-Cl. and J-Cl. Ruwet, 1982 Ecology and distribution of tilapias. p. 15-60. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds.) The biology and culture of tilapias. ICLARM Conf. Proc. 7.

Platt, S., and W.J. Hauser. 1978. Optimum temperature for feeding and growth of *Tilapia zilli.* Progressive Fish Culturist 40(3):105-107.

Potts, W.T.W., M.A. Foster, P.P. Rudy, and G.P. Howells. 1967. Sodium and water balance in the cichlid teleost, *Tilapia mossambica*. Journal of Experimental Biology 47:461-70.

Pullin, R. 1988. Tilapia genetic resources for aquaculture. ICLARM, Manila, Philippines.

Pullin, R.S.V. and R.H. Lowe-McConnell (eds.). 1982. The biology and culture of tilapias. International Centre for Living Aquatic Resources Management, Manila.

Ron, B., S. K. Shimoda, G.K. Iwama and E.G. Grau, 1995. Relationships among ration, salinity, 17 alpha-methyltestosterone and growth in the euryhaline tilapia, *Oreochromis mossambicus*. Aquaculture 135:185–193.

Stauffer, R.R. 1986. Effects of salinity on preferred and lethal temperatures of the Mozambique tilapia, *Oreochromis mossambicus* (Peters). Water Resources Bulletin 22:205-208.

Talbot, F. and B. Newell. 1957. A preliminary note on the breeding and growth of tilapia. E. Afr. Agricul. J. 22: 118-121.

Trewavas, E. 1983. Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museum Nat. Hist., London.

Villegas, C.T. 1990. Growth and survival of *Oreochromis niloticus*, *O. mossambicus* and their F1 hybrids at various salinities. Proceedings of the 2nd Asian Fisheries Forum, Tokyo, Japan, 17-22 April 1989. Asian Fisheries Society, Manila. p. 507-510.

Villegas, C.T. 1990. Salinity tolerance of *Oreochromis mossambicus*, *O. niloticus* and their F sub 1 hybrids. Asian Aquacult. 12 (3): 6-8.

Watanabe, W.O. 1991. Saltwater culture of tilapia in the Caribbean. World Aquaculture 22:49-54.

Watanabe, W. 1997. Saltwater culture of the Florida red and other saline-tolerant tilapias: a review, p. 55-141. In: B. Costa-Pierce and J. Rakocy (eds.) Tilapia aquaculture in the Americas. World Aquaculture Society Books, Baton Rouge, LA.

Watanabe, W.O., L.J. Ellingson, R.I. Wicklund, B.L. Olla. 1988. The effects of salinity on growth, food consumption and conversion in juvenile, monosex male Florida red tilapia. ICLARM Conf. Proc. 15: 515-523

Watanabe, W.O., K.E. French, L.J. Ellingson, R.I. Wicklund, B.L. Olla. 1988. Further investigations on the effects of salinity on growth in Florida red tilapia: evidence for the influence of behavior. ICLARM Conf. Proc. 15: 525-530.

Watanabe, W.O., K.E. French, D.H. Ernst, B.L. Olla, R.I. Wicklund. 1989. Salinity during early development influences growth and survival of Florida red tilapia in brackish and seawater. J. World Aquacult. Soc. 20 (3): 134-142.

Watanabe, W.O., K.M. Burnett, B.L. Olla, R.I. Wicklund. 1989. The effects of salinity on reproductive performance of Florida red tilapia. J. World Aquacult. Soc. 20:223-229.

Watanabe, W.O., R.I. Wicklund, B.L. Olla, D.H. Ernst. 1991. Rearing experiments with Florida red tilapia for saltwater culture. Proc. Gulf Caribb. Fish Inst. 40: 405-412.

Whitfield, A.K. and S.J.M. Blaber. 1979. The distribution of the freshwater cichlid *Sarotherodon mossambicus* in estuarine systems. Environmental Biology of Fishes 4:77-81.

Yu, T.C. and J.Y. Lay. 1990. Comparison of tilapia growth rates cultured in different salinity levels. Bull. Taiwan Fish. Res. Inst. 48: 173-177.

Yu, T.C. and J.Y. Lay. 1989. The growth comparisons of tilapia (*Oreochromis* sp.) cultured in different salinities of seawater. Bull. Taiwan Fish. Res. Inst. 46: 185-188.

Yu, T.C., T.Y. Lay, and J.T. Wu. 1988. The growth comparison of tilapia (*Tilapia* spp.) cultured in different salinity of sea water. Bull. Taiwan Fish. Res. Inst. 44: 145-150

MILKFISH (*Chanos chanos*)

Available References

Alcantara, L.B. 2000. The Water and Sediment Quality of *Chanos chanos* Monoculture and *Chanos chanos - Gracilariopsis bailinae* Biculture in Pond. Aquatic Science and Technology Institute. Science Diliman Vol. 12, No. 1 (January to June 2000)

A short-term study on the physical-chemical parameters in *Chanos chanos* monoculture and its biculture with *Gracilariopsis bailinae* indicated that the biculture might be advantageous for the growth of milkfish. Dissolved oxygen of the biculture and monoculture was not significantly different early in the morning. The afternoon DO of the biculture, however, was higher than that of the monoculture. There was no difference in pH readings between the monoculture and the biculture. Water temperature ranged from 23 to 39°C, and salinity ranged from 14 to 42‰ for both monoculture and biculture. The presence of *G. bailinae* did not affect water pH, temperature, and salinity of the biculture pond. *Chanos chanos* grew better in biculture with *G. bailinae* as the effect of more favorable water and sediment quality in the pond during the culture period. Furthermore, the nutrients present in the pond water and sediment were probably utilized by *G. bailinae* for their growth or stored in their tissues.

Bagarinao, T. and I. Lantin-Olaguer. 1999. The sulfide tolerance of milkfish and tilapia in relation to fish kills in farms and natural waters in the Philippines. Hydrobiolgia 382: 137-150.

Juvenile milkfish can tolerate 0 to 110‰ and temperatures of 15 to 41°C if given time to acclimate. Sulfide tolerance of 2-5 g milkfish and 5-8 g tilapia was determined with flow-through sea water (30 to 32‰ at 100 ml/min) at 26-30°C and sulfide stock solution pumped in at 1 ml/min. Total sulfide at 2.2 mg/l or H2S at 313 µg/l was lethal to 50 percent of fish in 4 to 8 hours. Milkfish ranging from 5 to 12 g died in 5 to 8 hours when DO was 1 mg/l (declining from 6 mg/l). Mortality occurred in 7 to 9 hours at pH of 3. Sulfide, low DO, and low pH are all toxic to milkfish and act synergistically to increase toxicity when combined.

Baylon, J.C., 1983 Factors affecting survival of milkfish, *Chanos chanos* fry and fingerling: different pH-salinity and temperature-salinity conditions. Fish. Res. J. Philipp. 8(1):44-49.

Survival of milkfish fry and fingerlings was determined at different pH-salinity and temperature-salinity combinations after 96 hours of exposure. The pH-salinity combination with the highest survival (93.5 percent) of fry was at pH 7.0 in 15‰ salinity and lowest survival (10 percent) was at a combination of pH 5.0 with 0‰ salinity. For the fingerlings, highest survival (95.7 percent) was at pH 8.0 in 30‰ salinity and lowest (18 percent) at pH 5.0 with 45‰ salinity.

Fry survival of 100 percent was observed at a cold water temperature (21-23°C) with 15‰ salinity, and a lower survival of 70 percent was obtained at a warm water temperature (32-35°C) with 30‰ salinity. For the fingerlings, 100 percent survival occurred at 15‰ salinity for all temperature levels (cold, warm), and a lower survival of 93.3 percent was observed in warm water at 30‰ salinity.

Duenas, C.E. and P.S. Young. 1983. Salinity tolerance and resistance of milkfish larvae. Second International Milkfish Aquaculture Conference Iloilo City, Philippines. 4–8 October 1983.

The lower and upper salinity tolerance limits of hatchery-bred milkfish larvae were determined at days 0, 7, 14 and 21 after hatching. Larval samples reared in ambient salinities of 28 to 32‰ were exposed to different levels of test salinities (e.g., 0 to 56‰ for 0, 7, and 14 day old, 0 to 100‰ for 21 day old) for a maximum of 48 hours. Median tolerance limits (TLm) at 6-, 24-, and 48-hour exposure periods were estimated from the time-mortality and salinity-mortality data. Results showed that the tolerance of larvae to salinity varied with age. Newly hatched larvae (Day-0) had a wider zone of tolerance than l- and 14-day old larvae, but 21 day old larvae had the widest tolerance among ages tested. The 48-hr TLm values (‰) of larvae tested were: Day 0: 8 to 37‰; Day 7: 27 to 28‰; Day 14: 6 to 28‰; and Day 21: 0 to 70‰. In higher salinities, tolerance was lowest at day 7 and highest at day 21, while in lower salinities, tolerance widened with age except at day 7. TLm values at 6- and 24-hour exposure periods showed similar trends. Seven-day old larvae were most sensitive to salinity changes and handling stress due to transfer. At this stage, the tolerance zone of larvae was narrowed to its ambient or original salinity (27 to 28‰). Abrupt transfer to other salinities caused substantial mortality, but it was lowest at 16‰ indicating that a transfer salinity with an osmotic concentration near that of the body fluid could favor larval survival. For 14-day old larvae, salinities from 6 to 28‰ define their zone of tolerance, and salinities from 8 to 16‰ probably provide the least osmotic stress. Twenty-one-day old larvae were most tolerant to salinity changes, their tolerance limits already established within 6 hours of exposure.

In a companion study involving tests of wild caught fry maintained at 28‰ and 26-day old hatchery-bred larvae acclimated in three salinities, the following results were obtained: 1) The upper median tolerance limit of wild caught fry tested at salinities from 56 to 80‰ was 70‰, a value similar to that of 21-day old hatchery-bred larvae; and 2) all 26-day old hatchery-bred larvae acclimated in salinities of 8, 16, and 24‰ for 5 days and tested at 80‰ all died, but the time to 50 percent death (ET50) was influenced by the acclimation salinity. Larvae obtained from 24‰ died in 3.9 hours while those from 8‰ died in 1.2 hours. This suggests that the resistance and tolerance limits of larvae are also influenced by their acclimation history.

Ferraris, R.P., J.M.E. Almendras, A.P. Jazul and J.M. Ladja. 1983. Preliminary studies on ion and osmoregulation in milkfish. Second International Milkfish Aquaculture Conference. Iloilo City, Philippines. 4–8 October 1983.

The osmoregulatory capability of milkfish juveniles for three size ranges (40 g, 120 g, and 260 g) was studied. The fish were acclimated to 32‰ and abruptly transferred to 0, 16, 32, and 48‰. Blood samples were taken at 0, 1, 2, 3, 5, 7, and 14 days after transfer while intestinal fluid samples were collected at days 0 and 14. Plasma osmolalities in fish exposed to salinities other than 32‰ deviated from the initial and control values immediately after transfer but were subsequently regulated to near-normal levels after several days. Plasma chloride values followed the same pattern of changes as the plasma osmolality. Values of blood parameters began to stabilize on the third day for the 260-g fish, on the fifth day for 120-g, and on the seventh day for the 40-g juveniles. Results also showed that smaller fishes have larger changes in blood parameter values after transfer to salinities other than the control while bigger ones have smaller but still significant changes. This suggests that bigger fishes are more efficient in handling ionic and osmotic induced stress. Intestinal fluid osmolality showed consistently higher values in the anterior than in the posterior regions in all treatments. On the other hand, chloride concentration was consistently higher in the posterior region. In fish kept at 32 and 48‰, chloride concentration in the anterior intestine was significantly less than the surrounding medium indicating that absorption of chloride occurred in regions more anterior to the intestine.

Garcia, Luis Maria B. 1988. Fisheries Biology of Milkfish (*Chanos chanos* Forskal). Technical Report in Proceedings of the regional workshop on milkfish culture development in the South Pacific. Tarawa, Kiribati, 21–25 November 1988. Accessed online at: http://www.fao.org/docrep/field/003/AC282E/AC282E00.htm

Low temperature (23°C) decreases survival, activity, food intake, and growth and development of milkfish fry and juveniles; high temperatures (up to 33°C) have the opposite effect. Lethal temperatures for juveniles are 42.7°C and 8.5°C although their tolerance limits vary with acclimation temperature.

Tolerance of milkfish juveniles to low dissolved oxygen levels also varies with the size of the animal. Larger fish seem to be tolerant of low dissolved oxygen levels in ponds. Symptoms of asphyxiation are discernible at 1.4 ppm oxygen among 200 to 300 g fish; 50 percent mortality occurs at around 0.1 to 0.4 ppm at 31 to 34°C.

Tolerance limits to salinity vary with age. Hence, seven day old larvae are most sensitive to salinity changes and handling stress, tolerating only levels within the range of 16 to 20 ppt. In contrast, 21 day old milkfish fry can tolerate salinities within the range of 0 to 70 ppt. The ability of fry to withstand salinity extremes may be related to their ability to gradually alter their chloride cell density and size and plasma osmolalities and chloride levels to near normal. In fact, reduction of salinity to 20 to 25 ppt during storage of milkfish fry enhances survival by possibly reducing osmotic stress. Chloride cell density and size of freshwater acclimated fry tend to be elevated with transfer to elevated salinities. As with temperature, tolerance limits to salinity extremes are influenced by acclimation history.

While milkfish fry can tolerate abrupt transfer from full-strength seawater to freshwater, early juveniles would die. However, milkfish juveniles can also tolerate a wide range of salinity (7.8 to 108.6 ppt), with larger fish more efficient at handling osmotic stress than smaller ones. Adult milkfish occur in hypersaline lagoons (158 ppt) in Christmas Island.

Guanzon, N.G., T.R. de Castro-Mallare, and F.M. Lorque. 2004. Polyculture of milkfish *Chanos chanos* (Forsskal) and the red seaweed *Gracilariopsis bailinae* (Zang et Xia) in brackish water earthen ponds. Aquaculture Research 35(5): 423-431.

Growth, net production, and survival rates of milkfish cultured with *Gracilariopsis bailinae* in brackish water earthen ponds over four culture periods were determined. The control was stocked at 30 fingerlings per 100-m^2 pond. No significant differences in mean growth, survival, and net production rates of milkfish among the three treatments were found. Irrespective of stocking singly or in combination with *G. bailinae*, significantly higher mean growth and mean production rates for milkfish were obtained during the third culture period of year 1 than in the other culture periods. Survival rates were not significantly different among the four culture periods. Significantly higher mean specific growth and mean net production rates of red seaweed were also obtained during the third culture period of year 1. The production of milkfish and red seaweed was higher during the dry season. Growth rate of milkfish was positively correlated with temperature and salinity, while net production rates were positively correlated with temperature and total rainfall but were inversely correlated with dissolved oxygen.

Juliano, R.O. and H.R. Rabanal. 1963. The tolerance of milkfish fingerlings and fry, *Chanos chanos* (Forskal) to decrease in salinity. Copeia. 1: 180–181.

The Dagat-dagatan Saltwater Fisheries Station of the Philippines Bureau of Fisheries conducted experiments on the tolerance of milkfish fingerlings to changes from salt to brackish water to slightly saline water and proved their osmoregulatory capacity to be within the limits of 20 to 30 parts per thousand of sudden change. Sudden changes in salinity were made from 38 to 5‰, 32.9 to 8.3‰, 25.4 to 5.1‰, and 20 to 5.7‰. Mortalities in the experiments were 40, 0, 0, and 1 percent, respectively. However, sudden changes from salt or brackish water to totally fresh water usually resulted in mass mortality. Exceptions were in sudden shifts from 20.4‰ and 20‰ to totally fresh water in which mortalities of 66 percent and 28 percent, respectively, were recorded. According to the data presented, no matter how abrupt the change was, the fingerlings tolerated a wide range of decreasing salinity provided the change was not to totally fresh water.

Acclimatization from salt to fresh water proved more successful with fry than with fingerlings. The fry adjusted to sudden change in salinity from 30.2‰ to fresh water without mortality. However, the sudden change in salinity produced crooked bodies of the fry probably due to the sudden change in pressure of the water medium. The calcium content of the bones may be involved in these morphological anomalies. The difference in tolerance of fingerlings and fry to dilution of salt water may be due to size. Apparently the relatively greater area of the gill surface in the smaller fish helped during temporary respiratory stress as a result of dilution of water. Osmotic pressure may also be a factor here but no explanation could be offered on this basis at present.

Lin, Y.M., C.N. Chen and T.H. Lee. 2003. The expression of gill Na, K-ATPase in milkfish, *Chanos chanos*, acclimated to seawater, brackish water and fresh water. Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology 135(3): 489-497.

Juvenile milkfish *Chanos chanos* (Forsskål, 1775) were transferred from a local fish farm to fresh water (FW; 0‰), brackish water (BW; 10‰, 20‰) and seawater (SW; 35‰) conditions in the laboratory and reared for at least two weeks. The blood and gill of the fish adapted to various salinities were analyzed to determine the osmoregulatory ability of this euryhaline species. No significant difference was found in plasma osmolality, sodium or chloride concentrations of milkfish adapted to various salinities. In FW, the fish exhibited the highest specific activity of Na, K-ATPase (NKA) in gills, while the SW group was found to have the lowest. Relative abundance of branchial NKA α-subunit revealed similar profiles. However, contrary to other euryhaline teleosts, i.e. tilapia, salmon and eel, the naturally SW-dwelling milkfish expresses higher activity of NKA in BW and FW. Immunocytochemical staining has shown that most Na, K-ATPase immunoreactive (NKIR) cells in fish adapted to BW and SW were localized to the filaments with very few on the lamellae. Moreover, in FW-adapted milkfish, the number of NKIR cells found on the lamellae increased significantly. Such responses as elevated NKIR cell number and NKA activity are thought to improve the osmoregulatory capacity of the milkfish in hyposaline environments.

Swanson, C. 1991. Aspects of the physiology of salinity adaptation in the milkfish, *Chanos chanos* forskal, during two life history stages. Ph.D. Thesis UCLA.

The physiological responses of milkfish (*Chanos chanos*) to salinity were investigated using a bioenergetic approach. Two life history stages, eggs and larvae, and juveniles, were chronically exposed to salinities from 15 to 55 ppt. Metabolism, growth, yolk absorption (eggs and larvae), activity (juveniles), and the effects of activity on osmoregulatory ability (juveniles) were measured. Salinity significantly affected the energy relations of both life history stages but variations in energy allocation patterns were not consistently related to the osmotic gradient between the organism and environment.

During early development, salinity affected metabolic rates by influencing yolk absorption and embryonic growth. Metabolic rates increased with age and were directly related to the amount of embryonic tissue. Eggs incubated in 35 ppt had higher metabolic rates than those from the low or high salinities and produced the largest larvae. Low salinities retarded growth and yolk absorption and produced small larvae with large yolk reserves. High salinities decreased yolk utilization efficiency; larvae were small with small yolk reserves.

For juvenile milkfish, salinity affected metabolism primarily through its influence on spontaneous activity. Routine metabolic rates were directly related to swimming speeds and preferred swimming speeds differed among the salinities. Milkfish swam at the highest speeds in 35 ppt and had high metabolic rates. Fish in 15 and 55 ppt had equally low metabolic rates but different preferred swimming speeds; fish in 55 ppt swam slower than those in 15 ppt. Reduced activity in the high salinity may have compensated for elevated osmoregulatory costs. High salinities may have limited activity. Milkfish in 15 ppt were able to sustain higher swimming speeds than fish in 35 and 55 ppt. Fatigue in the high salinities may have resulted from osmoregulatory failure. Sustained activity reduced osmoregulatory abilities of fish in 55 ppt. Differences in metabolism and activity were reflected by differences in growth; milkfish had higher growth rates in 55 ppt than in 35 ppt. For both life history stages, osmoregulatory costs were probably small and less important to the overall energy relations of the organism than salinity-related differences in growth and/or activity.

Swanson, C. 1998. Interactive effects of salinity on metabolic rate, activity, growth and osmoregulation in the euryhaline milkfish (*Chanos chanos*) J. Exp. Biol. 201: 3355-3366.

In this study, energy partitioning for metabolism, activity and growth, maximal activity performance and blood osmotic concentrations were assessed at two activity levels in juvenile milkfish fed equal rations and maintained at a relatively constant temperature (26±2 °C) and at salinities (15, 35 and 55‰) that represented a wide range of osmoregulatory challenges. Routine oxygen consumption rates were high in 35‰ salinity and comparably low in 15 and 55‰ salinity. Routine activity levels (relative swimming velocity) were highest in 35‰ salinity, intermediate in 15‰ salinity and lowest in 55‰ salinity. Growth was significantly higher in 55‰ salinity than in 35‰ salinity and intermediate in 15‰ salinity. Maximum swimming velocities decreased with increases in salinity. Sustained swimming activity above routine levels for 2 hours resulted in an increase in blood osmotic concentrations in milkfish in 55‰ salinity, but osmoregulation was re-established during the second 2 hours of activity. Reduced osmoregulatory abilities and reductions in maximal swimming performance suggest that high salinity may constrain activity. The results demonstrate that investigations of salinity adaptation in euryhaline fishes should take into account the interactive effects of salinity on physiology and behavior.

Villaluz, A.C. and A. Unggui. 1983. Effects of temperature on behavior, growth, development and survival in young milkfish, *Chanos chanos* (Forskal). Aquaculture 35: 321-330.

Effects of three temperature treatments on activity, feeding, growth, development and survival of young milkfish (*Chanos chanos*) were investigated. Low temperature (<22.6°C) and hypoxial condition (<1 ppm O_2) decreased activity, responsiveness and food intake; high temperature (up to 33°C) had the opposite effect. Growth and development were fastest in fish maintained in high temperature ($\bar{x} = 29.5°C$). Fish in low temperature ($\bar{x} = 20.7°C$) had the least growth and were inhibited from developing into juveniles during the 3-month period. Highest survival ($\bar{x} = 99.7\%$) was obtained in high temperature but was not significantly different (P>0.05) from ambient temperature.

Other Citations

Almendras, J.M.E. 1982. Changes in the osmotic and tonic content of milkfish fry and fingerlings during transfer to different test salinities. MSc Thesis. University of the Philippines. 29 pp.

Bagarinao, T. 1994. Systematics, distribution, genetics and life history of milkfish, *Chanos chanos*. Environmental Biology of Fishes 39(1): 23-41.

Crear, D. 1980. Observations on the reproductive state of milkfish populations (*Chanos chanos*) from hypersaline ponds on Christmas Island (Pacific Ocean). Proc. 11th Ann. Meet. Soc. 11: 548–556.

Gerochi, D.D., P.G. Padlan, I.G. Buenconsejo, J.N. Paw and E.M. Rodriguez. 1978. Minimum dissolved oxygen tolerance of different sizes of milkfish. SEAFDEC Aquaculture Department Quart. Res. Rep. 2: 7–10.

Lin, H.S. 1969. Some aspects of milkfish ecology. Chinese-American Joint Commission for Rural Reconstruction Fish, Ser. 7: 68–90.

Schuster, W.H., 1960 Synopsis of biological data on milkfish *Chanos chanos* (Forsskål), 1775. FAO Fish. Biol. Synop. (4):pag. var.

Swanson, C. 1992. Culture of a euryhaline fish: Effects of salinity on metabolism, activity, and growth in the milkfish, *Chanos chanos*. Aquaculture 92: Growing Towards the 21st Century, 213-214.

Swanson, C. 1996. Early development of milkfish: effects of salinity on embryonic and larval metabolism, yolk absorption and growth. J. Fish. Biol. 48:405-421.

Villaluz, A.C. 1984. Collection, storage, transport and acclimation of milkfish fry and fingerlings. In Advances in milkfish Biology and Culture. (J.V. Juario, Ferraris, R.P. and Benitez, L.V., Eds.). Island Publishing House, Manila, pp. 85–96.

SARGO (*Anisotremus davidsonii*)

Available References

Matsui, M.L., G.L. Lattin, R. Moore, C. Mulski. and A.B. Bond. 1991. Salinity tolerance of *Anisotremus davidsonii*. Final Report, Federal Aid Project F-51-R, Study No. 2. California Department of Fish and Game. Sacramento, California.

Laboratory salinity bioassays were used to estimate the adult reproductive potential and fertilization and hatching success of sargo (*Anisotremus davidsonii*) at increasing levels of total dissolved solids (35, 40, 45, 50, and 55 ppt). Fish were collected from the Salton Sea, acclimated in the laboratory to Salton Sea water at these five levels and allowed to spawn naturally. Sargo did not spawn at 50 and 55 ppt and spawns at the remaining three salinities were asynchronous. Hatching success experiments consisted of four replicates of 100 eggs/beaker/salinity treatment. Egg mortality ranged across all treatments through time from three to 31 percent. There was a significant effect of parental salinity on egg mortality with lower parental salinity associated with a higher egg mortality. This may have been an artifact of the experimental design producing confounding temporal effects (45 ppt were run in June while the 35ppt were run in September). Eggs spawned by adults acclimated to 45 ppt water produced viable fertilized eggs, but the eggs failed to develop past the blastopore closure stage. Larval mortality varied from 66 to 76 percent and treatment salinity had a significant effect. At high salinities all the larva died.

ORANGEMOUTH CORVINA (*Cynoscion xanthulus*)

Available References

Matsui, M.L., G.L. Lattin, R. Moore, C. Mulski, and A.B. Bond. 1991. Salinity tolerance of *Cynoscion xanthulus*. Final Report, Federal Aid Project F-51-R, Study No. 2 California Department of Fish and Game. Sacramento, California.

Eggs and larvae of the sciaenid fish Orangemouth Corvina, *Cynoscion xanthulus*, were obtained from fish matured in the laboratory by photoperiod and temperature manipulation and induced to spawn by LH-RHa injections. The effects on gametes of parental salinity acclimation were also investigated. Successful gonadal maturation occurred in adult corvina acclimated to 35 through 50 ppt salinity. Significant growth also occurred in individuals acclimated to 35 through 50 ppt salinity. Reproductive failure of this species will occur with increased salinity due to insufficient osmotic capability in the eggs and larvae.

Prentice, John A. 1985. Orangemouth Corvina Survival in Fresh Water. The Progressive Fish-Culturist:. 47(1): 61–63.

Corvina from the Salton Sea were maintained at 32‰ for up to six months. To test response to freshwater, fish were exposed to 17‰ and reduced to freshwater at rates of 2 to 4‰ and 10‰. Fish became more excitable after conversion to freshwater and growth was reduced. Mortality occurred from 4 to 11 weeks after conversion and in most cases were apparently related to injury and resulting fungal infection after fish hit aquarium sides.

Other Citations

Prentice, J., R. Colura and B. Bumguardner. 1985. Observations on induced maturation and spawning of orangemouth corvina. Cal. Fish and Game 75: 27-32.

Howells, R.G. 1990. Preliminary examination of low salinity tolerance of sperm, fertilized eggs, and larvae of orangemouth corvina, *Cyanoscion xanthulus*. California Fish and Game 76(1): 58-62.

SHORTFIN CORVINA (*Cynoscion parvipinnis*)

No salinity tolerance data found on this species.

GULF CROAKER (*Bairdiella icistia*)

Available References

Chao, L.N., 1995. Sciaenidae. Corvinas, barbiches, bombaches, corvinatas, corvinetas, corvinillas, lambes, pescadillas, roncachos, verrugatos. p. 1427-1518. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter and V. Niem (eds.) Guia FAO para identificacion de especies para los fines de la pesca. Pacifico Centro-oriental. 3 volumes. 1813 p.

Inhabits coastal waters, estuaries and river mouths

May, R. 1976. Effects of Salton sea water on the eggs and larvae of *Bairdiella icistia*. California Fish and Game 62: 119-131.

In laboratory experiments, eggs and early larvae of the sciaenid fish *Bairdiella icistia* survived well in sea water but displayed extremely poor survival in water from the Salton Sea. Mortality in Salton Sea water was expressed mainly among hatched larvae prior to complete yolk absorption. Experiments conducted in both natural and artificial sea water and Salton Sea water indicated that this poor survival was related to the unusual ionic composition of the Salton Sea.

May, R. 1975. Effects of temperature and salinity on fertilization, embryonic development, and hatching in *Bairdiella icistia* (Pisces: Sciaenidae), and the effect of parental salinity acclimation on embryonic and larval salinity tolerance. Fishery Bulletin 73(1):1-21.

Eggs and larvae of the sciaenid fish bairdiella, *Bairdiella icistia*, were obtained from fish matured in the laboratory by photoperiod manipulation and induced to spawn by hormone injections. The effects of temperature and salinity on fertilization, embryonic development, hatching, and early larval survival were studied with the material thus obtained, and the effects on gametes of parental salinity acclimation were also investigated. Fertilization took place over a wide range of temperatures and salinities, but was completely blocked at salinities of 10 ppt and below. A low level of spermatozoan activity may have accounted for the lack of fertilization at low salinities. Successful embryonic development occurred between temperatures of approximately 20 degrees and 30 degrees C, and salinities of 15 and 40 ppt. The production of viable larvae was estimated to be optimal at a temperature of 24.5 degrees C and a salinity of 26.6 ppt. An interaction of the two factors was apparent, development at high salinities being most successful at low temperatures and development at high temperatures being most successful at low salinities. The stage of maturity of the spawning female had a great influence on the overall viability of the eggs produced, as well as on their response to temperature and salinity. Adult bairdiella matured sexually in dilute seawater with a salinity of 15 ppt, and the salinity tolerance of the eggs produced by these fish was unaltered.

May, R. 1975. The effects of acclimation on the temperature and salinity tolerance of the yolk-sac larvae of *Bairdiella icistia*. (Pisces:Sciaenidae). Fishery Bulletin 73:249-255.

Eggs of the bairdiella, *Bairdiella icistia*, were fertilized and incubated in various combinations of temperature and salinity, and the salinity and upper thermal tolerances of the yolk-sac larvae were determined. The upper thermal tolerance was enhanced by acclimation to high temperatures and low salinities. Acclimation to low salinities enhanced the lower salinity tolerance of larvae at 24 hours after exposure to test conditions, but an acclimation effect on the upper salinity tolerance was not apparent until 48 hours after exposure. Yolk-sac bairdiella larvae are more tolerant than embryonic stages and less tolerant than adults to extremes of temperature and salinity.

Other Citations

May, R. C., 1974. Factors affecting buoyancy in the eggs of *Bairdiella icistia*. Mar. Biol. 28:55-59.

YELLOWFIN CROAKER (*Umbrina roncador*)

See "Multiple Species" References: Skogsberg, 1939; Starks, 1919; Cailliet, 2000.

Range: California, Point Conception, to southern Baja California, Bahia Magdalena. **Depth**: surf to 10 meters. **Longevity**: >10 yrs. Spawns in California and fertile March to August. Habitat types are sandy bottoms, bays and sloughs, surf, and artificial reefs. Feeding type is carnivore/benthivore. Nocturnal; school during the day, disperse at night to feed.

WHITE CROAKER (*Genyonemus lineatus*)

See "Multiple Species" References: Chao, 1995.

Benthopelagic; marine. Found over sandy bottoms.

GREEN JACK (*Caranx caballus*)

See "Multiple Species" References: Godinez-Dominguez et al., 2000.

Larvae were most abundant off the central west coast of Mexico in 1995-1996 in the fall when water temperatures were 27 to 29°C and salinity was 33.4 to 34‰.

Smith-Vaniz, W.F., 1995. Carangidae. Jureles, pámpanos, cojinúas, zapateros, cocineros, casabes, macarelas, chicharros, jorobados, medregales, pez pilota. p. 940-986. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter and V. Niem (eds.) Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental. 3 Vols. FAO, Rome.

Found on the continental shelf, generally near the coast but also in deeper waters; penetrated estuaries. Juveniles are often found in estuarine waters. Pelagic; brackish; marine; depth range 3 - 100 m.

PACIFIC CREVALLE JACK (*Caranx caninus*)

See "Multiple Species" References: Godinez-Dominguez et al., 2000.

Caranx caninus occurred normally during tropical periods and year-round during the anomalous period. *C. caninus* composed 19.2 percent of the total abundance during the survey and was one of 10 species that occurred in all 12 sampling months.

Madrid, J., P. Sanchez, and A.A. Ruiz. 1997. Diversity and Abundance of a Tropical Fishery on the Pacific Shelf of Michoacan, Mexico. Estuarine, Coastal and Shelf Science 45(4): 485-495.

This study shows the importance of seasonal variations on the abundance of Pacific crevalle jack in the study area. The present community abundance and diversity index under study is biased towards winter influences when the sea temperature decreases, rain influence is low, and turbidity is low. The abundances are possibly influenced by the availability of resources that are enhanced by low temperatures and upwelling events in the area.

RED DRUM (*Sciaenops ocellata*)

Available References

Arnold, C. R., G. J. Holt, and P. Thomas. 1988. Red drum aquaculture: proceedings of a symposium on the culture of red drum and other warm water fishes. Red Drum Research Symposium, June 22-24, 1987, Corpus Christi, Texas, USA. Port Aransas, Tex.: Marine Science Institute, the University of Texas at Austin.

Robinson, Edwin H. Nutritional requirements of red drum: a review.

Numerous studies have documented the feeding habits of red drum, *Sciaenops ocellatus*, in nature. Based on inferences drawn from these studies and on data from nutritional studies with other fish, red drum are expected to require the same nutrients for normal metabolic function as other fish. Studies indicated that red drum are carnivorous and depend on crustaceans and fish as their major food source. A study conducted in South Florida found shrimp to be the most important food item for red drum during July and September, and crabs were the most important item during other periods. A study of red drum in southeastern Louisiana found fish to be the main food item during the winter and spring. Fourteen species were indicated as prey for red drum with the predominate one being menhaden. Crustaceans comprised the bulk of their diet during summer and fall. A study conducted from Mississippi Sound to the northern Gulf of Mexico reported the diets of most red drum larvae and juveniles were dominated by copepods and crustacean nauplii. Crustacean eggs and decapod post-larvae were also important food items.

Gatlin, D.M. III, D.S. Mackenzie, S.R. Craig, and W.H. Neill. 1992. Effects of Dietary Sodium Chloride on Red Drum Juveniles in Waters of Various Salinities. The Progressive Fish-Culturist 54 (4): 220–227.

Three 8-week feeding trials were conducted to determine the effects of supplemental dietary salts on growth and osmoregulation of juvenile red drums (*Sciaenops ocellatus*) at various water salinities. In each experiment, sodium chloride was added to a basal diet composed of semipurified and practical ingredients; the basal diet provided intrinsic levels of 0.80 percent Cl, 0.84 percent K, and 0.92 percent Na on a dry-matter basis. Results from these experiments indicate that dietary supplementation with NaCI improved the growth of red drums in dilute (fresh and brackish) waters, but not in full-strength seawater. Dietary salts for red drums in dilute waters may provide ions that the fish cannot sufficiently extract from hypotonic environments.

Procarione, L.S. and T.L. King. 1993. Upper and Lower Temperature Tolerance Limits for Juvenile Red Drums from Texas and South Carolina. Journal of Aquatic Animal Health 5(3): 208–212.

Upper and lower temperature tolerance limits, reported as temperatures lethal to 50 percent of the test fish (LT50s), were determined for juveniles of red drum *Sciaenops ocellatus* obtained from Texas and South Carolina brood stock. This information on red drum thermal tolerance limits was used to determine whether a more northerly distributed population exhibits greater cold tolerance and could therefore be used to improve success of stocking programs. A 96-hour temperature tolerance test was performed on juveniles (71-155 mm total length) acclimated to water temperatures ranging from 12.0 to 28.0°C at a salinity of 20‰. Test fish were transferred directly into a series of high-temperature (27.0-37.0°C) or low-temperature (2.0-16.0°C) water baths. The upper LT50 for Texas red drums acclimated to 28.0°C was within 1.1 °C of that calculated for South Carolina red drums acclimated to the same temperature (upper LT50s were 35.7 and 34.6°C). Upper LT50s for fish acclimated to 20.0 and 12.0°C were also similar between the two stocks. Likewise, lower LT50s were similar between the two stocks of red drums: as determined from fish acclimated to 14.0 and 28.0°C, ranges of lower LT50s were 2.8-9.0°C for the Texas stock and 2.69.3°C for the South Carolina stock. The lower LT50 could not be determined for red drums acclimated to 12.0°C, because only three fish died. No consistent differences in temperature tolerance limits were found between the two hatchery stocks, precluding any recommendation to stock one group instead of the other.

Stanton, J.L., J.B. Wiley, and L.A. Tucci. 2000. Effects of Temperature on Production Characteristics of Red Drum, *Sciaenops ocellatus*. Journal of Applied Aquaculture 10 (2): 73-78.

Red drum, *Sciaenops ocellatus*, fingerlings cultured in recirculating systems for 56 days at 18, 22, 26, 30, or 34º C in salinities of 5 and 10 ppt exhibited best growth at 30.4º C in 5 ppt and 31.1º C in 10 ppt. Growth ranged from 7 to 125 percent. Survival and condition factor were not affected by temperature. The results of this study indicate that optimization of temperature in red drum culture systems will have profound effects on productivity.

Swarajyalakshmi, G., P. Gurumurthy, and G.V. Subbaiah. 2000. Effects of Salinity on Production Characteristics of Red Drum, *Sciaenops ocellatus*. Journal of Applied Aquaculture 10 (2): 67-71.

Red drum, *Sciaenops ocellatus*, were cultured for 56 days at 29.5º C in water containing either 5 g/l or 10 g/l sea salts. Fish cultured in the lower salinity exhibited significantly better growth (161 percent vs. 136 percent) and feed conversion ratios (2.26 vs. 2.49) than fish cultured in the higher salinity. Condition factor (1.01) and survival (97-100 percent) were not affected by salinity. Culture of red drum in low-salinity water offers advantages over culture in high-salinity water such as lower costs for reconstituting water, more flexibility in siting farms, and protection against the pathogenic dinoflagellate *Amyloodinium*.

Weirich, C.R. and J.R. Tomasso. 1991: Confinement- and Transport-Induced Stress on Red Drum Juveniles: Effect of Salinity. The Progressive Fish-Culturist 53(3): 146–149.

Fingerling red drums (*Sciaenops ocellatus*; mean weight ± SE, 28.0 ± 0.9 g to 42.3 ± 1.1 g) were acclimated to salinities of 2, 4, 8, 16, or 35‰ (25°C) and then crowded in cages for up to 48 hours. Fish in the intermediate salinities survived whereas most fish in the two extreme salinities died. Plasma osmolality values increased in fish confined in 35‰ salinity, decreased in fish confined in 2‰ water, and were stable in the fish confined in the intermediate salinities. All fish (weight, 20.2 ± 1.2 g to 37.1 ± 1.7 g) survived 9 hours of simulated transport and a 3-day follow up in 2, 4, 8, 16, or 35‰ salinity at temperatures of 25 or 30°C. Results of this study and others indicate that healthy red drum fingerlings tolerate confinement and transport well. Further, survival is enhanced if fish are handled and transported in water that is nearly isosmotic with the plasma of the fish (approximately 11‰).

Other Citations

Chung, K.S., G.J. Holt and C.R. Arnold. 1993. Influence of salinity and food deprivation on growth and RNA-DNA ratio in red drum Sciaenops ocellatus (Pisces, Sciaenidae). Revista de Biologia Tropical 41: 2:187-195.

Crocker, P.A., C.R. Arnold, J.A. DeBoer, and J. Holt. 1981. Preliminary evaluation of survival and growth of juvenile red drum (Sciaenops ocellata), in fresh and salt water. Journal of the World Mariculture Society 12:122-134.

Fuiman, L.A. and D.R. Ottey, 1993 Temperature effects on spontaneous behavior of larval and juvenile red drum Sciaenops ocellatus, and implications for foraging. Fish. Bull. 91:23-35.

Holt, G.J. and C.R. Arnold. 1981. Effects of temperature on early development of red drum (Sciaenops ocellata). Fifth Annual Larval Fish Conference. March 2-3, 1981. Louisiana State University, Baton Rouge, LA. Page 83.

Holt, G.J. and M.A. Banks. 1988. Salinity tolerance and development of osmoregulation in larval sciaenids. Early Life History Symposium, ICES, #63.

Holt, J., R. Godbout, and C.R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum, Sciaenops ocellata. Fishery Bulletin 79(3):569-573.

ANCHOVETA (*Cetengraulis mysticetus*)

See "Multiple Species" References: Franco-Gordo et al., 2003.

Larvae were most abundant off the central west coast of Mexico in 1995-1996 in the spring when water temperatures were 22 to 25°C and salinity was 34.4 to 34.8‰.

Bayliff, W.H. 1969 Synopsis of biological data on the anchoveta *Cetengraulis mysticetus* Günther, 1866. FAO Spec. Synop. 43.

This is a collection of natural history and biological data on the anchoveta for the purpose of disseminating information.

The anchoveta has been recorded in the Pacific ocean from San Pedro, California to Sechura Bay, Peru. In the Gulf of Panama, adults and spawning occur over shallow mud flats, and the eggs and larvae are found there. The juveniles are found at the surface, often near rocky islands in water to about 60 meters deep. The most conspicuous predator of the adult anchoveta is the pelican (*Pelecanus occidentalis carolinensis*). Other predators include the frigate bird (*Fregata magnificens*), and various large fishes like *Cynoscion othonopterus* and *C. macdonaldi*. Juvenile anchoveta feed on plankton including mainly diatoms and also flagellates and crustaceans. Adults also feed primarily on diatoms.

Peterson, C. L. 1961. Fecundity of the anchoveta (*Cetegraulis mysticetus*) in the Gulf of Panama. Inter-American Tropical Tuna Commission, La Jolla, Ca.

One aspect of the work of the Inter-American Tropical Tuna Commission is to investigate the biology, life history, and ecology of the anchoveta (*Cetengraulis mysticetus*) to make possible an understanding of the effects of the fishery on this species. An earlier study found that just prior to spawning, the ovaries of anchoveta from the Gulf of Panama contain only a single mode of maturing ova and a second mode of immature ova. Researchers concluded that the female anchoveta probably spawns only one batch of eggs per season and that the ova in the secondary mode degenerate and are absorbed. In this study, these findings are assumed and thus the total fecundity of a specimen can be estimated simply by determining the number of ova in the most advanced mode.

Length, weight and age of 86 anchoveta were recorded and fecundity relations studied for each. Length (in millimeters) versus number of ova in most advanced mode (in thousands) was plotted, and the result showed an increasing line, meaning that in general longer fish produced more ova. However, there was considerable variation in fecundity of individual fish of the same length. The weight-fecundity relationship was also positive, meaning in general with increased weight the fecundity also increased. No method has yet been found for determining the age of individual specimens of anchoveta; however, studies show that it is reasonable to assume that the anchoveta population is over 90 percent first year fish, less than 10 percent second year fish, and less that 1 percent in their third year. The study also indicated that first year females are 120 to 135 mm long in the spawning season. Therefore, it is likely that the majority of spawning female anchovetas contribute 20,000 to 35,000 eggs each during the course of the spawning season.

PACIFIC FLAGFIN MOJARRA (*Eucinostomus currani*)

De La Cruz Agüero, J. 1997. Catalogo de los peces marinos de Baja California Sur. IPN-CICIMAR, La Paz, Mexico. p. 341.

Juveniles are commonly found in estuarine regions, mangroves, tidal streams and rivers far from the coast. Adults occur in deeper waters.

SILVER MOJARRA (*Eucinostomus argenteus*)

Waldinger, F. J. 1968. Relationships of environmental parameters and catch of three species of the mojarra family (Gerridae), *Eucinostomus gula*, *Eucinostomus argenteus*, and *Diapterus plumieri*, collected in 1963 and 1964 in Buttonwood Canal, Everglades National Park, Florida. M.S. Thesis, Univ. of Miami, Miami, Fla. 68 pp. http://everglades.fiu.edu/research/schmidt/citationsd.html

Favors high salinity. Enters freshwater. Juveniles are encountered in lagoons of mangroves. Habitat: estuary, lagoon, brackish, mangroves, marshes, swamps.

SALEMA (*Xenistius californiensis*)

No salinity tolerance data found for this species.

LONGFIN SALEMA (*Xenichthys xanti*)

See “Multiple Species” References: Schmidt, 1991.

PORGY (*Calamus brachysomus*)

Lockington, W.N. 1880. Description of a new sparoid fish (*Sparus brachysomus*) from Lower California. Proc. U.S. Natl. Mus. 3 (149): 284-286.

LONGSPINE PORGY (*Stenotomus caprinus*)

FishBase 2000. Published by the International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati City, Philippines

The longspine porgy is sub-tropical and has a low resilience with a minimum population doubling time of 4.5 to 14 years. Their depth range is 5 to 185 meters (16 to 610 feet), and the fish are found mainly on muddy bottoms.

Caldwell, D. K. 1955. Distribution of the longspined porgy, *Stenotomus caprinus*. Bulletin of Marine Science of the Gulf and Caribbean 5: 230-239.

MEXICAN GOATFISH (*Mulloidichthys dentatus*)

No salinity tolerance data found for this species.

CODLET (*Bregmaceros bathymaster*)

See “Multiple Species” References: Franco-Gordo et al., 2003.

Larvae were most abundant off the central west coast of Mexico in 1995-1996 in the spring when water temperatures were 22 to 25°C and salinity was 34.4 to 34.8‰. This species was the most dominant found with a relative density range of 77 to 98 percent.

OCEAN WHITEFISH (*Caulolatilus princeps*)

See "Multiple Species" References: Cailliet, 2000.

Range: British Columbia to Peru, including Gulf of California and Islas Galapagos. **Depth**: shallow water to 136 m. **Longevity**: 13 yrs. Spawning and fertile November to March. Larvae are in coastal waters to >200 miles offshore; adults are offshore over rocky reefs and around islands.

Moser, H.G., B.Y. Sumida, D.A. Ambrose, E.M. Sandknop, and E.G. Stevens. 1986. Development and distribution of larvae and pelagic juveniles of ocean whitefish, *Caulolatilus princeps*, in the CalCOFI survey region. California Cooperative Oceanic Fisheries Investigations Reports 27: 162-169.

Ocean whitefish distribution is temperature dependent; ocean whitefish have warm-water affinity and congregate within 100 miles of the coast. Larvae occurred from Ensenada to Magdalena Bay and seaward to Guadalupe Island. Occurrences were concentrated off central Baja California. It is apparent from the distribution of larvae that ocean whitefish populations off California are recruited from Baja California.

FishBase 2000. Published by the International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati City, Philippines.

Ocean whitefish are sub-tropical and have a low resilience with a minimum population doubling time of 4.5 to 14 years. Their depth range is 10 to 91 meters (33 to 300 feet), and they inhabit rocky bottoms but are also found on soft sand and mud. They dig into the substrate for food.

BIGHEAD TILEFISH (*Caulolatilus affinis*)

See Ocean Whitefish: Moser et al., 1986

Ocean whitefish distribution is temperature dependent; ocean whitefish have warm-water affinity and congregate within 100 miles of the coast. Larvae occurred from Ensenada to Magdalena Bay and seaward to Guadalupe Island. Occurrences were concentrated off central Baja California. It is apparent from the distribution of larvae that ocean whitefish populations off California are recruited from Baja California.

FishBase 2000. Published by the International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati City, Philippines.

Bighead tilefish are tropical and have a low resilience with a minimum population doubling time of 4.5 to 14 years. Their depth range is 30 to 185 meters (100 to 610 feet), and they inhabit rocky and sandy bottoms near isolated reefs.

MexFish.com. 2004. Pacific Golden-Eyed Tilefish, Blanquillo (Caulolatilus affinis). Accessed online at: http://www.mexfish.com/fish/pgeyetile/pgeyetile.htm

Bighead tilefish are found at depths between 100 and 600 feet in the water column over both rock and sand bottoms.

Dooley, J.K. 1978. Systematics and biology of the tilefishes (Perciformes: Branchiostegidae and Malacanthidae) with descriptions of two new species. NOAA Tech. Rep. NMFS Circ. No. 411: 1-78.

Elorduy-Garay, J.F. and S.S. Ruiz-Cordova. 1998. Age, growth, and mortality of Caulolatilus affinis (Osteichthyes: Branchiostegidae) from the Southern Gulf of California. Pac. Sci. 52(3): 259-272.

DEEPBODY ANCHOVY (*Anchoa compressa*)

Emmett, R.L., S.L. Stone, S.A. Hinton, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: species life history summaries. ELMR Rep. No. 8 NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD. 329 pp.

All life stages live primarily in estuaries, bays, and lagoons, but schools of juveniles and adults are occasionally found along coastal shorelines. Because this is a pelagic species, all life stages are found over various substrates. Population abundances of this species were significantly correlated with temperature and dissolved oxygen. However, thermal and salinity tolerances have not been identified.

BLUE BOBO (*Polydactylus approximans*)

Schneider, M. 1995. Polynemidae. Barbudos. p. 1386-1387. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter and V. Niem (eds.) Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental. 3 Vols. FAO, Rome.

Found in shallow water near the coast, on sand and mud bottoms. Larvae and small juveniles (>4 cm) are pelagic and sometimes occur several hundred kilometers offshore, whereas the larger juveniles and adults prefer shallow near-shore waters like bays, sloughs or estuaries where the bottom is sandy or muddy.

WHITE SEA BASS (*Cynoscion nobilis*)

See "Multiple Species" References: Cailliet, 2000.

Range: Alaska to southern Baja California and northern Gulf of California. Depth: inshore to 122 m. Longevity: >20 yrs. Spawning and fertile from March to September. Larvae are planktonic in inshore waters and are carnivores of crustaceans; juveniles are in shallow sandy habitat with vegetation and are carnivores of small fish; adults are in kelp forests, sandy bottoms, artificial reefs and are carnivores of fish, crab, squid, etc. Adults are both schooling and solitary.

Edwards, R.R.C. 1976. Ecology of a Coastal Lagoon Complex in Mexico. Est. Coast Mar. Sci. 6:75-92. (Available from ScienceDirect for $30)

Measurements were made on primary production, oxygen consumption of substrate, and biomass of invertebrates and fish in a Mexican coastal lagoon. Juvenile white seabass, Cynoscion nobilis were found in a lagoon on the Pacific Coast of Mexico where dry season average monthly salinity was measured as high as 60 ‰but where lower salinity water was usually available (35 ‰). The actual salinity at the time and location of collection of these fish is not reported.

QUEENFISH (*Seriphus politus*)

See "Multiple Species" References: Chao, 1995.

Common in bays and tidal sloughs, around pilings. Demersal; marine ; depth range 1 - 21 m. Occurs inshore, often over sandy bottoms.

MULTIPLE SPECIES (INCLUDING PROPOSED LIST)

Available References

Baltz, D.M., J.W. Fleeger, C.F. Rakocinski, and J.N. McCall. 1998. Food, density, and microhabitat: factors affecting growth and recruitment potential of juvenile saltmarsh fishes. Environmental Biology of Fishes 53: 89-103.

Salinity, temperature, and DO influenced growth of juvenile seatrout and red drum (<50 mm standard length) more than diet or Spartina alterniflora stem density in estuarine nursery areas of Barataria and Caminada bays, Louisiana. Seatrout were found in water at 24.5 to 33.0°C, with 4.2 to 8.8 mg/l DO, and a salinity of 10 to 27.2‰. Food consisted of a calanoid copepod (Acartia tonsa) when the fish were small with a switch to mysid shrimp (Americamysis almyra and Taphromysis louisiana) as they grew larger. Marsh edge habitat was important.

Brocksen, R.W. and R.E. Cole. 1972. Physiological responses of three species of fishes to various salinities. Journal of the Fisheries Research Board of Canada 29:399-405.

The effects of varying salinity on parameters such as growth, food consumption, food conversion efficiency, and respiration were determined for three species of fish inhabiting the Salton Sea, California. Bairdiella (Bairdiella icistia), orangemouth corvina (Cynoscion xanthulus), and sargo (Anisotremus davidsoni), were subjected to salinities ranging between 29 and 45 ppt. The optimal range of salinity was between 33 and 37 ppt for all three species. Growth, food consumption, food assimilation, and respiration were adversely affected at the extreme salinities of 29 and 45 ppt. The results indicate that the fish inhabiting the Salton Sea will experience difficulty in maintaining populations of the current size when the salinity reaches 40 ppt.

Cailliet, G.M. 2000. Final Report, Biological Characteristics of Nearshore Fishes of California: A Review of Existing Knowledge and Proposed Additional Studies. Submitted to: Pacific States Marine Fisheries Commission. August 31, 2000.

Collection of data includes range, depths, longevity, spawning period, habitat types, feeding types, and active periods.

Camacho, A.S., T. Abella, and M.M. Tayamen. 2001. Fish genetics research and development in the Philippines, p. 71-76 In M. V. Gupta and B. O. Acosta (eds.). Fish genetics research in member countries and institutions of the International Network on Genetics in Aquaculture. ICLARM Conf. Proc. 64: 179 p.

Overview of genetic research in the Philippines includes a classical breeding program for the development of saline-tolerant tilapia for brackish water aquaculture. To increase tilapia production and productivity of brackish water ponds, the fish are being selected and developed to withstand saline and high water temperature conditions. The study used strains of *Oreochromis mossambicus* and *O. niloticus*. Results revealed that salinity tolerances varied among the crosses. The upper limit of salinity for all was 25 ppt. Some of the studies conducted include comparison of the protein banding patterns of milkfish (*Chanos chanos*).

Dill, W.A., and A.J. Cordone. 1997. History and status of introduced fishes in California, 1871-1996. Manuscript for Fish Bulletin of the California Department of Fish and Game 178.

This is a chronicle of the origin of the fishes actually introduced into the waters of the state of California, those recorded as introduced, and those proposed as likely for introduction, as well as their subsequent history. A complete list of the fishes introduced into Salton Sea is reproduced here. The anchoveta also was introduced unsuccessfully several times from Mexico into the Salton Sea. Of the Mexican fish, these have been introduced successfully: Bairdiella and orangemouth corvina. These were unsuccessful: anchovy, *Eucinostomus gracilis*, white mullet, *Colpichthys regis*, flounder, and halibut.

Franco-Gordo, C., E. Godínez-Domínguez, E. Suárez, and L. Vásquez-Yeomans. 2003. Diversity of ichthyoplankton in the central Mexican Pacific: a seasonal survey. Estuarine, Coastal and Shelf Science 57: 111-121. (Available from ScienceDirect for $30)

The seasonal variation in the diversity of ichthyoplankton was analyzed from samples collected monthly during a year cycle off the central Pacific coast of Mexico. Samples were collected using a Bongo net at 12 stations during 11 months, from December 1995 through December 1996. The most dominant species was *Bregmaceros bathymaster*, its relative density varied between 77 and 98 percent. Two main seasonal patterns were revealed after analyzing the dynamics of the coastal water mass and the ichthyoplankton assemblage ordination in relation to diversity. Diversity values (jack-knifed H=0.24) were relatively low from January to May, and indicated a first seasonal pattern, related to a period dominated by the influence of the California Current, with surface temperatures ranging between 21 and 24 °C. The second pattern was featured by diversity values five-fold higher than in the winter-spring (H=0.92). These were related to the influence of warm, tropical waters from the Equatorial Countercurrent, with associated temperatures ranging between 26 and 29.2 °C. A transitional period was identified in June and December; it represented a mixed assemblage and yielded the highest richness. Diversity null models were useful as tools to confirm the major seasonal patterns of the surveyed ichthyoplankton community.

Godinez-Dominguez, E., J. Rojo-Vazquez, V. Galvan-Pina, and B. Aguilar-Palomino. 2000. Changes in the Structure of a Coastal Fish Assemblage Exploited by a Small Scale Gillnet Fishery During an El Nino-La Nina Event. Estuarine, Coastal and Shelf Science 51(6): 773-787. June. (Available from ScienceDirect for $30)

During 1998 an experimental gillnet fishing survey was carried out in a Mexican Central Pacific inshore zone. One-hundred and thirty fish species belonging to 51 families and 18 orders were identified. The most abundant species were *Microlepidotus brevipinnis* (29·0 percent of the total abundance) and *Caranx caninus* (19·2 percent), followed by *C. caballus* (6·3 percent), *Kyphosus analogus* (4·3 percent) and *C. sexfasciatus* (3·4 percent). Thermal SST anomalies showed the existence of two periods. The first, from January to April with positive anomalies, defines the end of an El Niño episode. The second period, from May to December, constitutes the beginning of the La Niña episode. The typical seasonality in a non-anomalous year continued for a large percentage of the inshore fish community, and the effects of the anomalous event consisted of changes in seasonality of occurrence in some individual species and the unusual abundance of some uncommon species. The species richness was higher during the El Niño–La Niña event than in a non-anomalous year, and therefore the event could be considered an interannual environmental mechanism that favours fish diversity in inshore waters.

Hanson, J.A. 1970. Salinity tolerances for Salton Sea fishes. California Department of Fish and Game. Inland Fisheries Administrative Report 70-2.

Salinity tolerances were determined for bairdiella (*Bairdiella icistuis*), orangemouth corvina (*Cynoscion xanthulus*), and sargo (*Anisotremus davidsoni*). In 96-hour shock bioassays, over half the bairdiella died at salinities 55 and 57.5 ppt, and only 2 of 30 survived at 62.5. Most orangemouth corvina survived to 57.5 ppt, but all died at 62.5. Significant numbers of sargo died at all levels from 45 through 57.5 ppt, and all died at 62.5. Survival of sargo in the controls was only 89.6 percent, suggesting that some mortality was caused by other factors. *Bairdiella*, given an opportunity to adjust to hypersalinity, survived for eight days at 58 ppt.

Lasker, R., R.H. Tenaza and L.L. Chamberlain. 1972. The response of Salton Sea fish eggs and larvae to salinity stress. California Fish and Game 58:58-66.

In laboratory experiments, Salton Sea water at salinities of 40 parts per thousand and higher adversely affected developing embryos and larvae of the croaker, *Bairdiella icistia*, and the sargo, *Anisotremus davidsoni*. Embryos developed abnormally, hatching success diminished, and mortality of larvae was greater than in normal Salton Sea water at 37.6 parts per thousand.

Riedel, R., L. Caskey, and B.A. Costa-Pierce. 2002. Fish biology and fisheries ecology of the Salton Sea, California, Hydrobiologia, Volume 473, Issue 1-3, April 2002, Pages 229–244.

Studies of the fisheries ecology and fish biology of the Salton Sea, California, were conducted in 1999 and 2000 using 50-meter gill nets in river, nearshore, pelagic, and estuarine areas. Ten fish species were captured of which hybrid tilapia (*Oreochromis mossambicus* x *O. urolepis hornorum*) was dominant by number and weight. Nearshore and estuarine areas had the highest catch rates (over 11 kg/h/net for tilapia). Orangemouth corvina (*Cynoscion xanthulus*), bairdiella (*Bairdiella icistia*), sargo (*Anisotremus davidsoni*), and tilapia grew faster, but had shorter life spans than conspecifics elsewhere and Salton Sea conspecifics of 50 years ago. Reproduction occurred mostly in the nearshore and estuarine areas. Gender ratios of tilapia were skewed toward males in all areas, except the rivers, where females predominated. All four species aggregated along the nearshore and estuarine areas in the summer when dissolved oxygen in the pelagic area was limited.

Schmidt, T.W. 1991. Scientific Studies in the Coastal and Estuarine Areas of Everglades National Park: An Annotated Bibliography. National Park Service, Southeast Region Research/Resources Management Report SER-91/1.

A total of 493 references (published and unpublished) on scientific studies in the coastal and estuarine areas of Everglades National Park (ENP) were annotated and subsequently indexed and arranged according to major scientific topics including zoology, geology, botany, hydrometeorology, water quality, and pollution. The geographic focus was three major estuaries located within the boundaries of ENP. Studies from a wider area were included if they also sampled in park estuaries. This report was developed to provide researchers and resource managers with access to the rapidly accumulating body of information on the park's marine resources. It may be considered current through December 1989. Many references listed were completed during the last decade.

Skogsberg, T. 1939. The fishes of the family Sciaenidae (croakers) of California. California Department of Fish and Game, Fish Bulletin 54.

The writer of this paper attempted to treat of the family Sciaenidae, one of the many families of the California fishes, in such a manner that the results could be used as a model for other contributions toward a proposed handbook. Circumstances prevented him from doing intensive and extensive studies in the field, especially in regard to the difficult chapter on the breeding habits and life-histories, but he plans to accumulate information of this kind in the years to come and to record and store it in such a manner that it will be readily available to whomsoever will become the editor of the handbook.

The most outstanding feature of the treatment of the material presented in this paper is the strict standardization of diagnoses and descriptions. All the characters are treated in a standard sequence and, as far as possible, in the same terminology. This strictness has been adopted in order to facilitate comparisons. In the arrangement of the characters the most logical order has been sought: first, the general shape of the body; second, the external features of the head; third, the external features of the rest of the body; fourth, the internal features of the head; and, fifth, the internal features of the rest of the body. Then follow the coloration and size, a series of proportions, and finally a statement as to the number and sizes of the specimens examined.

Walker, B.W., ed. 1961. The ecology of the Salton Sea, California, in relation to the sportfishery. Calif. Dept. Fish and Game, Fish Bull. 113: 204 p.

In 1949 there were four species of fishes in the Sea: desert pupfish (*Cyprinodon macularius*), mosquitofish (*Gambusia affinis affinis*), striped mullet (*Mugil cephalus*), and longjaw mudsucker (*Gillichthys mirabilis*). The most important food chain to the sportfishery is: phytoplankton → zooplankton → detritus → detritus eating worm (*Neanthes*) → worm-eating fish (bairdiella and sargo) → fish-eating fish (corvina). The weakest link in this chain is at the level represented by Neanthes. This single species is the only organism in the Sea converting detritus into food for bairdiella and sargo. This stage in the chain is probably strong as regards to efficiency, however. Of secondary importance is the food chain: phytoplankton → zooplankton → threadfin shad → corvina.

Wang, Tian-Yuan. 2003. Study on the oxygen tolerance of milkfish (*Chanos chanos*), mullet (*Liza macrolepis*) and Tilapia (*Oreochromis mossambicus*). Masters Thesis. NSYSU Taiwan. (Have PDF)

Laboratory tolerance experiments of fish fry, including mullet (*Liza macrolepis*), milkfish (*Chanos chanos*) and tilapia (*Oreochromis mossambicus*), exposed to low levels of dissolved oxygen were conducted in the period of January 2002 to April 2003. At water temperature of 23º C, median lethal times (LT50) and 48 hours median lethal concentrations (48-hour LC50) at the salinity of 10‰, 20‰ and 30‰ were determined, respectively. Under the condition of 20‰ salinity, the tolerance of low dissolved oxygen for the three species of fish fry were significantly different. Among them, milkfish was found to be the most sensitive species, followed by mullet, whereas tilapia was the most tolerant species. The 48-hour LC50s of milkfish, mullet and tilapia were 15.7, 8.6 and 7.8 percent air saturation, respectively, which were 1.16, 0.63 and 0.57 mg/l at 23º C. Similarly, the LT50s also showed species-specific differences. At DO level of 0.52 mg/l, the LT50s were 77.9 minutes for milkfish, 245.7 minutes for mullet and over 1000 minutes for tilapia. The DO lethal concentrations of mullet fry increased with the decrease of salinity, but not the case for milkfish fry. The 48-hour LC50 of mullet fry in 30‰ saline water was 11.5 percent air saturation (0.8 mg/l), which was higher than those in 10‰ and 20‰ saline water. However, no significant difference in 48h LC50 was found between milkfish kept in 10‰ and 20‰ saline water. The 48-hour LC50 for the former was 14.9 percent air saturation while the latter was 15.7 percent. Both are equivalent to 1.16 mg/l at water temperature of 23º C.

Other Citations

Eschmeyer, W.N., E.S. Herald and H. Hammann, 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A. 336 p.

Hiatt, R.W. 1944. Food chains and the food cycle in Hawaiian fish ponds. Pt.1. The food and feeding habits of mullet (*Mugil cephalus*), milkfish (*Chanos chanos*) and the tenpounder (*Elops machnata*). Trans. Am. Fish. Soc. 74: 250-261.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(2): 175-192.

Simmons, E. G., 1957. An ecological survey of the upper Laguna Madre of Texas. Pub. Inst. Mar. Sci. Texas 4:156-200.

Starks, E.C. 1919. The fishes of the croaker family (Sciaenidae) of California. California Fish and Game 5: 13-20.

Thomson, D.A. 1987. Reef fishes of the Sea of Cortez. The rocky-shore fishes of the Gulf of California. The University of Arizona Press, Tuscon. 302p.

Thomson, D.A., L.T. Findley, and A.N. Kerstitch. 2000. Reef fishes of the Sea of Cortez. The rocky-shore fishes of the Gulf of California. (Revised edition) University of Texas Press, Austin, Texas, U.S.A. 353 pp.