Saltwater cichlids. Knowledge of salinity tolerance and preference may allow new species combinations and improved husbandry in aquaria.

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Maybe you have been in your local fish shop and have seen the occasional molly swimming gleefully in a saltwater tank. You stop, puzzled. Upon inquiring, you learn that mollies often live in coastal estuary and lagoon habitats, capitalizing on that middle ground between land and sea. The store representative tells you that it is not that hard to convert such a fish from freshwater to full strength seawater. You find it interesting, but move on. Most people that invest in marine aquaria yearn for the brilliant colors typical of reef dwelling species, or robust predators that would make short work of a molly. However, would you be surprised to know that several cichlids are also tolerant of full strength seawater? Knowledge of salinity tolerance could open doors to housing new combinations of species, and knowledge of salinity preference could bring an aquarist one step closer to providing ideal husbandry.

One of the primary characteristics of life is homeostasis, the maintenance of a constant internal environment in the face of changing external factors. Teleost fishes maintain constant internal concentrations of ions and water that are different than that of the surrounding medium. They accomplish this through the functions of the gills, kidneys, skin, gut, and urinary bladder. A fish in a hypo-osmotic medium like seawater maintains a higher concentration of water and lower concentrations of ions than in the surrounding fluid. This creates a concentration gradient, and results in osmosis: transport of water out of the fish's body. The fish responds by drinking more than it would in an isotonic solution. The swallowed water is absorbed by the gut along with dissolved ions like sodium (Na^+), potassium (K^+), and chloride (Cl^-). Surplus ions are secreted out of the body by chloride cells embedded in the gill epithelia. Saltwater adapted fish have more mitochondria and extensive invaginations in the chloride cells that aid them in secreting excess ions. Freshwater is hyper-osmotic to a fish and water diffuses in through the gills. This causes the fish to excrete large amounts of dilute urine and take up needed ions like Na^+ and Cl^- through the gills (Karnaky 1998).

Cichlids have long been known to be euryhaline, or tolerant of a wide range in salinity. Some cichlid aquarists believe that their fish do better with salt, and regularly add it with each water change. In fact, salt is known to prevent infection in wounded cichlids (Aronson 1951). Cichlidae is one of four families in the suborder Labroidei (Stiassny and Jensen 1987), along with Pomacentridae (damselfishes and clownfishes), Labridae (wrasses and parrotfishes), and Embiotocidae (surf perches). Of these four sister families, only Cichlidae is generally freshwater.

Some cichlids occur in salty water. Some of the most basal cichlids, the Indian chromides (*Etroplus* spp.), have been observed in Negombo Lagoon, Sri Lanka at salinities ranging from 24-29 ppt (parts per thousand) (Ward and Wyman 1977). Full strength seawater is considered to generally be about 35 ppt (Cole 1998), and Fenner (1998) recommends maintaining saltwater aquaria between specific gravities of 1.020-1.025, which is about 27.30-33.75 ppt. The tilapia *Oreochromis mossambicus* inhabits estuaries and can endure levels of salinity higher than that of seawater (Whitfield and Blaber 1979). The physiologies of tilapia have been studied extensively because they are commonly grown in aquaculture for human consumption. Some tilapia have been found to grow better in brackish water than in freshwater (Martinez-Palacios et al. 1990). Some new world cichlids can also endure salty water. *Cichlasoma bimaculatum* lives in estuaries in Trinidad, the Guianas, and Brazil at salinities up to 15 ppt (Zaneveld 1983). Other cichlids live in isolated inland lakes where, for thousands of years, water has evaporated and left minerals behind, resulting in lakes with high ion concentrations.

Of the 100 or so species of Central American cichlids (Staeck and Linke 1995), two can regularly be found in the ocean: the black belt cichlid (*Vieja maculicauda*) and the Mayan cichlid ('Cichlasoma' *urophthalmus*) (Figure 1). In Belize the black belt has only been seen in fresh water, but it is known to inhabit brackish water in Panama (Greenfield and Thomerson 1997). It is restricted to coastal habitats in Costa Rica (Bussing 1987), and has been caught in the mangrove shorelines of Corn Island, 30 miles off the coast of Nicaragua in the Caribbean Sea (Conkel 1993). The Mayan cichlid has been seen on the northern rocky coast of Isla Mujeres, one mile off the coast of Cancun (Conkel 1993), and has been observed spawning in pure seawater behind St. Georges Cay, which is three miles off-shore of Belize City (Conkel 1993, Greenfield and Thomerson 1997). Near Progreso,

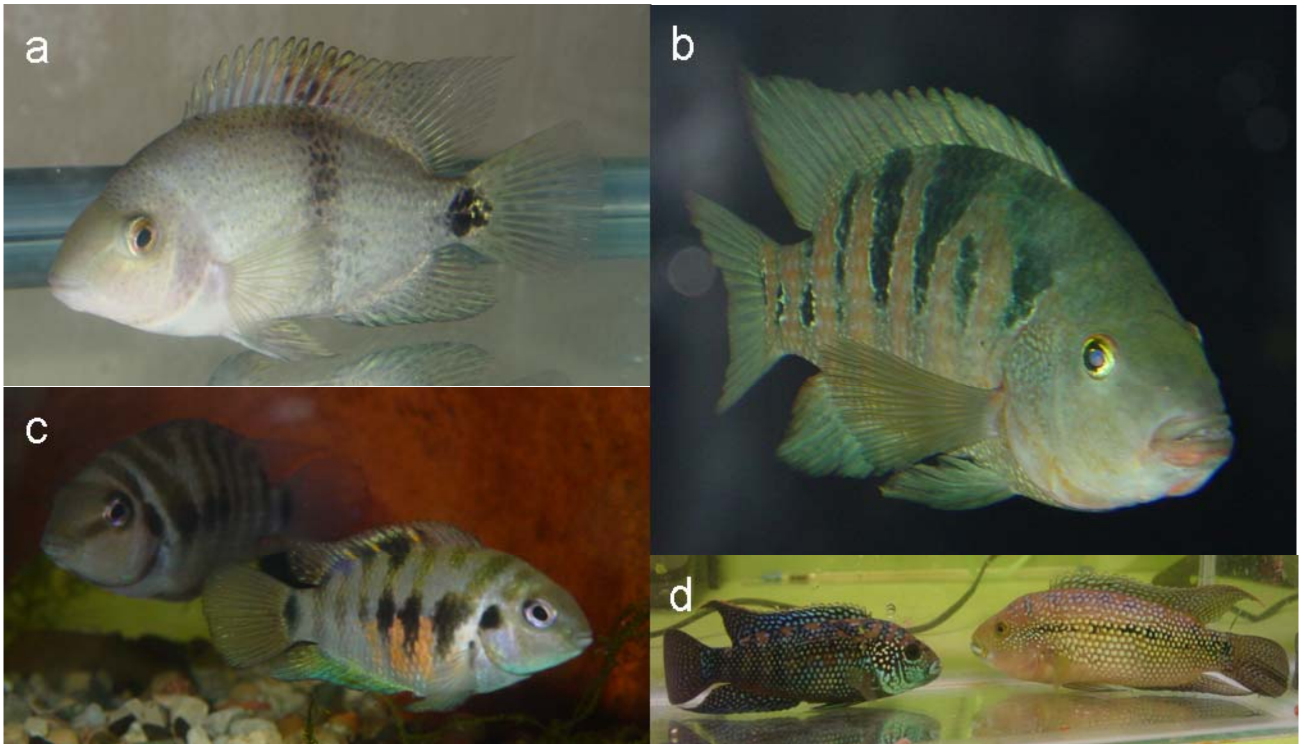

Figure 1. Some Central American cichlids are tolerant of brackish water. The (a) blackbelt, *Vieja maculicauda*, and the (b) Mayan, 'Cichlasoma' *urophthalmus*, cichlids can tolerate marine conditions, while the (c) convict, *Archocentrus nigrofasciatus*, and (d) Jack Dempsey, 'Cichlasoma' *octofasciatum*, cichlids can live with low concentrations of salt.

Yucatan, ocean water has a salinity of 34 ppt (Martinez-Palacios et al. 1990).

Much research has been performed on salinity tolerance in the Mayan cichlid due to its potential as a food fish. In one study, juvenile Mayan cichlids lab-reared at 25° C in freshwater were slowly acclimated (2 ppt/day for four days at a time) to 30 ppt salinity without harm. Many survived when placed directly into salinities up to 37 ppt (Stauffer and Boltz 1994). Martinez-Palacios et al. have extensively investigated the physiology of the Mayan cichlid. They described successful acclimation up to salinities of 35 ppt by increasing salinity 5 ppt every 48 hours (Martinez-Palacios et al. 1990). They found the cichlids to be capable of withstanding direct transfer from freshwater to brackish water of 15 ppt at 28° C. However, half of the fish tested died within six days after being transferred directly to 24 ppt salinity. In order to find the salinity in which the fish grow best, fish were acclimated to saltwater concentrations of 0, 5, 10, 20, 30, and 35 ppt and grown out over long periods of time. They were found to grow best at the 10 and 20 ppt test salinities (Martinez-Palacios et al. 1990).

Despite the tolerance to saltwater of the black belt cichlid and Mayan cichlid, some species are not so flexible, and are considered to be stenohaline. Martinez-Palacios et al. also tested the redhead cichlid (*Vieja synspilum*). Like the test on the Mayans, redheads were also directly transferred to different salt concentrations at 28° C. While they showed about 90% survival in salinities up to 10 ppt, they were found to have a 50% survival rate at only 14.5 ppt, and are therefore much less salt tolerant than the Mayans (Martinez-Palacios et al. 1995).

In the remaining discussion, I will describe two undergraduate student research projects that were performed in order to gather information involving salinity tolerance and preference of four species of Central American cichlids. This information might be particularly valuable to aquarists, considering that the species tested are common aquarium inhabitants.

The first project was an attempt to acclimate two cichlid species to salt water, the 'red devil' common to the aquarium hobby (*Amphilophus* sp.) and the black belt cichlid. These species were expected to acclimate to full-strength seawater because of their natural habitats. The black belt occurs in marine environments and the fish sold in the pet trade as the red devil cichlid is likely to be a hybrid (Loiselle 1980) of different *Amphilophus* spp. (Heijns 2002) that occur in the great lakes and in the mineral-rich crater lakes of Nicaragua (Barlow 1976).

Only three individuals of each species were used in order to minimize suffering should they not be able to acclimate. Each species was placed into one standard '20-gallon high' aquarium that was ¾ filled with aged tap water maintained at 28° C. A drip method provided continuous increase in salinity, rather than several large increases, in an attempt to ease the transition. Synthetic seawater dripped from a five gallon plastic bottle into each fish tank over a period of four days. The salt concentration of the water in the bottles was four times that of seawater, so that each aquarium was full of 29.7 ppt salinity water by the fourth day.

None of the red devils survived the transition. Two died late on Day 3 at a salinity of 19.7 ppt and the third died early on Day 4 at a salinity of 21.4 ppt. All three of the black belts survived initially. However, the osmotic stress may have been too much for them, as two of the three died within a week after the experiment. One black belt did survive, however. It was eventually donated to the University of Toledo and displayed in a marine aquarium, where it cohabitated with damselfish and clownfish for over two years (final disposition unknown). The drip method may provide no advantage over staggered additions of salt. We can conclude that acclimation to salt water will require more than four days to be successful.

The second project employed a procedure to test the effects of salinity on individual physiology without causing the death of the animals. An experiment was performed that tested metabolic rate during a short duration of exposure to saltwater. If a fish has a genetic predisposition for freshwater, then its metabolic rate should increase when it is placed in brackish water. This would be the result of an increase in energy expenditure used to maintain the proper osmotic balance inside the fish's body. Although this type of experiment does not provide direct evidence of a species' ability to live in saltwater, it might tell us how euryhaline a fish is, and how easily it might acclimate to different salinities. Three species were tested: the goldfish (*Carassius auratus*), the convict cichlid (*Archocentrus nigrofasciatus*), and the Jack Dempsey ('Cichlasoma' *octofasciatum*). The goldfish was acclimated to and tested at 18° C, and both cichlids at 21° C. All fish were taken from aged tap water. Since goldfish are not known to be euryhaline, it was hypothesized that when transferred from freshwater to salty water they would show a greater increase in metabolic rate than the cichlids. Three individuals of each species were placed into freshwater and three into solutions of 10 ppt sodium sulfate. Sodium sulfate was used because it was thought to be less stressful to the fish than sodium chloride (Sushama Pavgi, personal communication). Oxygen consumption was recorded for each fish.

As expected, the goldfish had higher metabolic rates in brackish water than in freshwater, although the difference only approached significance (t = 3.32, two-tailed p = 0.08). The metabolic rates of the convict cichlids were similar in the two treatments (t = 0.85, two-tailed p = 0.49), and the Jack Dempseys' were actually lower in salty water (t = 7.89, two-tailed p = 0.001) (Figure 2). It seems that while the convicts were indifferent to the two treatments, the Jack Dempseys preferred the brackish water. However, the possibility remains that a stress induced activity reduction (which was not quantified) could also have yielded a lowered metabolic rate in the Dempseys.

All fish used in these two experiments were either acquired directly from the pet trade, or were descendents of fish acquired from the pet trade. Generations of inbreeding, selective breeding, or hybridization may have altered the genetic composition of the fish such that the observed salinity responses were not representative of wild individuals. In guppies, inbreeding has been shown to decrease salinity tolerance (Chiyokubu et al. 1998). However, the interspecies variation observed in both experiments indicates species-typical levels of tolerance. Also, the convicts, Dempseys, and red devils were spawned in the lab from female and male parents that had been obtained from different sources. The inbreeding depression observed in guppies was relieved in one generation of out-crossing (Chiyokubu et al. 1998).

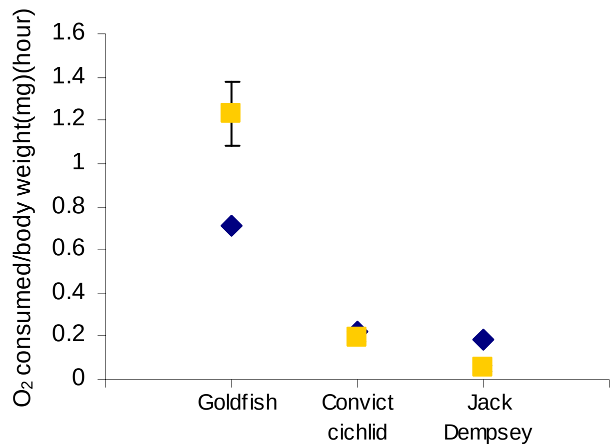

Figure 2. Metabolic rates of each of three fish species in fresh (diamonds) and brackish (10 ppt sodium sulfate, squares) water. Bars represent standard error.

The evidence from the literature and from these experiments shows that many species of Central American cichlids can withstand wide ranges of salinity. While some appear to be unaffected by low salt concentrations (convict, redhead), others prefer brackish water to freshwater (Mayan, Jack Dempsey). While full strength sea water may be too strong for some species if not given enough time to acclimate (Mayan, red devil, blackbelt), it is possible for some to make a complete transition if given enough time (Mayan, black belt).

The experiments reported here successfully gathered information while minimizing animal suffering. Both methods can use small sample sizes, and metabolic rate comparisons provide information on salinity preference without death or prolonged stress. Fish whose metabolic rates do not increase dramatically at extreme salinities may be candidates for saltwater conversion. Unfortunately, measuring metabolic rate may not be an option for many hobbyists because it requires an oxygen meter, and flasks and stoppers.

Knowledge of salinity tolerance could allow new captive species combinations. Knowledge of salinity preference could bring aquarists one step closer to providing ideal artificial conditions. I had assumed that a saltwater cichlid would be something coveted by aquarists, being a novelty, and because it combines two very popular approaches to keeping fish. However, the idea may be too unusual to be readily accepted. After I had succeeded in maintaining the lone surviving black belt, I tried to sell it to a pet store. I called a few local fish shops that had saltwater tanks but they were not interested. I think it likely that they just did not understand what I was offering. Regardless of commercial prospects, the potential for the hobbyist to acclimate his own cichlids to saltwater is apparent. The first step would be to consider the natural habitat of the species. If it comes from salty water, then the data presented here on acclimation time and salt concentration should be considered before conversion is attempted. However, if successful, the salty water may be more physiologically appropriate than freshwater.

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