

How do marine  
migratory fish adapt  
to freshwater  
conditions as they  
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Most marine fish spend the duration of their lives, from hatching to spawning and dying, in the salty waters of the sea to which they are adapted, just as most freshwater fish spend the duration of their lives in the freshwater of rivers and lakes to which they are adapted, this is mainly because they cannot tolerate major changes in salinity. These fish are known as stenohaline and make up around 95% of all fish. However, the remaining 5% are euryhaline fish, (according to Tang C, Tzeng C, and Hwang L et al. 2009), and they have the ability to tolerate the change in salinity between salt and freshwaters and travel between the two. Euryhaline fish include anadromous fish, which are born in fresh water but then make their way to the sea as juveniles to live, until they are mature, only to migrate back to freshwaters to spawn, and catadromous fish, which are born in saltwater but migrate to freshwater to mature before migrating back to the seas to spawn. Some anadromous fish species return to fresh water each year to spawn, such as the striped bass (*Morone saxatilis*), and some species only return to freshwater once to spawn before dying, such as the steelhead trout (*Oncorhynchus mykiss*).

## Main

For any fish to survive in the waters of its natural environment it has to maintain a constant salinity level in its blood stream which is more saline than freshwater (around 0.5 parts per thousand) but less saline than saltwater (around 35 parts per thousand) (United States Environmental Protection Agency, 2001), to regulate this salinity level they osmoregulate.

For a freshwater fish the water of its environment is hypotonic, due to osmosis the water diffuses into the body of the fish from the surrounding

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water, they compensate for this problem by expelling large quantities of the water as urine. To keep their blood salinity at the desired level they have chloride cells in their gills which enables them to absorb ions from the surrounding water. For a marine fish the surrounding seawater of its environment is hypertonic, therefore they lose water from their bodies to the surrounding waters due to osmosis, they compensate for this loss by drinking a large quantity of sea water each day but only producing a small amount of urine. With the use of the chloride cells in their gills they secrete the excess sodium ions they have also ingested back into the water so their blood salinity stays at the optimum level. The excretion of the ions back into the water uses a lot of energy as it involves moving them against the electrochemical gradient, the energy is provided by the sodium-potassium-ATPase ( $\text{Na}^+ - \text{Cl}^-$  ATPase).

The Atlantic salmon (*Salmo salar*) is an example of an anadromous euryhaline fish. They are spawned in rivers where they remain until they are large enough to survive in the sea, and eventually travel back to their spawning grounds to spawn themselves before they die. Because of this they have adaptations that enable them to thrive in both salt and fresh water environments. Whilst living in the sea, salmon like other marine fish, drink lots of water to balance the effects of osmosis and their kidneys produce small amounts of concentrated urine, but when salmon begin preparing to migrate into freshwaters to spawn they start to make the physiological changes needed for the transition whilst spending a few days in the intertidal zone. They stop drinking and their kidneys begin to produce a more dilute urine to balance the water that will diffuse into their bodies, as opposed to

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out when in the freshwater environment, and the molecule pumps in the cells of their gills need to begin pumping sodium ions in instead of out. “ In their gill epithelial cells, salmon have a special enzyme that hydrolyses ATP and uses the released energy to actively transport  $\text{Na}^+$  and  $\text{Cl}^-$  against their concentration gradients. In the ocean, the  $\text{Na}^+ - \text{Cl}^-$  ATPase molecules pump  $\text{Na}^+$  and  $\text{Cl}^-$  out of the salmon’s blood into the saltwater flowing over the gills. In fresh water, these same  $\text{Na}^+ - \text{Cl}^-$  ATPase molecules ‘ pump’  $\text{Na}^+$  and  $\text{Cl}^-$  out of the water flowing over the gills and into the salmon’s blood, thereby offsetting the continuous diffusion-driven loss of NaCl that the salmon is subject to in fresh water habitats with their vanishingly low NaCl concentrations”. (Evolution news, 2015)

Bull sharks (*Carcharhinus leucas*) like other shark species tend to live in the sea, but unlike the other species these sharks are also euryhaline as they also have the ability to travel into freshwater. This is because unlike other shark species, they have the ability to regulate the quantity of salt and urea in their body’s tissues which is needed to make the transition from salt to freshwaters. “ Bull sharks kidneys are capable of gradually adjusting to suit the salinity of the water they are in. As the bull shark enters freshwater, their kidneys stop removing as much salt and instead remove more urea from the bloodstream via urination”. (Alderson J, 2017) The sharks are constantly testing the salinity of the water with sensors on their body and the specialised gland acts as required releasing or retaining the salt. A study done by Beau D. Reilly, Rebecca L. Cramp, Jonathan M. Wilson, et al. has also identified, much like the salmon, “ ion regulatory cells in the gills of bull sharks that shows they possess the putative ion transporters necessary for <https://assignbuster.com/how-do-marine-migratory-fish-adapt-to-freshwater-conditions-as-they-move-into-freshwater-environments/>

the sodium and chlorine uptake in freshwater, and that the Sodium-hydrogen antiporter 3 protein and  $\text{Na}^+ - \text{Cl}^-$  ATPase messenger RNA were greater in the gills of bull sharks caught in freshwater indicating that the transporters play an enhanced osmoregulatory role when bull sharks are residents in freshwater environments". (Reilly B, Cramp R, Wilson J, et al. 2011)

Another experiment carried out on guppies (*Poecilia reticulata*), another euryhaline fish, found that, like in the salmon and bull shark the chloride cells play a major role in the adaptation to fresh and saltwater. The study showed that " two types of chloride cells were identified in freshwater-adapted guppies. One referred to as an alpha-chloride cell and the second a beta-chloride cell. The study showed that during seawater adaptation the alpha-chloride cells increased in size and transformed into seawater alpha-chloride cells, then underwent a progressive degeneration and disappeared. Showing that in freshwater-adapted guppies there are two types of chloride cells: alpha and beta, and in seawater-adapted fishes only a single type: alpha". (Pisam M, Caroff A, Rambourg A, 1987). Similarly an experiment carried out more recently on a euryhaline mummichog killifish (*Fundulus heteroclitus*) found, " saltwater and freshwater type chloride cells identified in killifish adapted to both salt and freshwater. Both types of chloride cell was equally active in the two environments, but exert different ion-transporting functions. Following direct transfer from salt to freshwater, the saltwater-type cells transformed into freshwater-type as a short-term response, followed by the promotion of chloride cell replacement as a long-term response". (Kaneko T, Katoh F, 2004) These experiments show how

euryhaline fish adapt their chloride cells to conduct the function needed for their current environment.

## Conclusion

If a stenohaline marine fish was placed in a freshwater environment the water surrounding the fish's body would diffuse through into the body causing the fish to swell, because stenohaline fish have no mechanism enabling them to remove the excess water it would eventually die. If a stenohaline freshwater fish was placed in a marine environment the water would diffuse out of the body causing the fish to dehydrate and die.

However, euryhaline fish retain both mechanisms which enables them to survive in both fresh and saltwater. They have the ability to excrete copious amounts of urine in freshwater to compensate for water diffusing into their body, and the ability to produce small amounts of urine in saltwater to compensate for the loss of water through osmosis. This, along with the chloride cells in euryhaline fish's gills adapting to the environment the fish is occupying by increasing in size and number, along with an increase in  $\text{Na}^+ - \text{Cl}^-$  ATPase in the cell after a transition from fresh to sea water, and reducing in number or entirely disappearing after a transition from seawater to freshwater. (Zadunaisky J, 1966) enables them to change environments with only a short period of time in intertidal zones to adjust. These adaptations allow marine euryhaline fish to take advantage of the freshwaters for safe spawning and growing grounds for their young and new food sources that would otherwise not be available to them.

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