Growth rate and age

A pair of sagittae from a Pacific Cod (*Gadus macrocephalus*).

Removing an otolith from a red snapper to determine its age

See also: estimating the age of fish

Finfish (class Osteichthyes) have three pairs of otoliths – the sagittae (singular sagitta), lapilli (singular lapillus), and asterisci (singular asteriscus). The sagittae are largest, found just behind the eyes and approximately level with them vertically. The lapilli and asterisci (smallest of the three) are located within the semicircular canals. The sagittae are normally composed of aragonite (although vaterite abnormalities can occur[13]), as are the lapilli, while the asterisci are normally composed of vaterite.

The shapes and proportional sizes of the otoliths vary with fish species. In general, fish from highly structured habitats such as reefs or rocky bottoms (e.g. snappers, groupers, many drums and croakers) will have larger otoliths than fish that spend most of their time swimming at high speed in straight lines in the open ocean (e.g. tuna, mackerel, dolphinfish). Flying fish have unusually large otoliths, possibly due to their need for balance when launching themselves out of the water to "fly" in the air. Often, the fish species can be identified from distinct morphological characteristics of an isolated otolith.

Fish otoliths accrete layers of calcium carbonate and gelatinous matrix throughout their lives. The accretion rate varies with growth of the fish – often less growth in winter and more in summer – which results in the appearance of rings that resemble tree rings. By counting the rings, it is possible to determine the age of the fish in years.[14] Typically the sagitta is used, as it is largest,[15] but sometimes lapilli are used if they have a more convenient shape. The asteriscus, which is smallest of the three, is rarely used in age and growth studies.

In addition, in most species the accretion of calcium carbonate and gelatinous matrix alternates on a daily cycle. It is therefore also possible to determine fish age in days.[16] This latter information is often obtained under a microscope, and provides significant data to early life history studies.

By measuring the thickness of individual rings, it has been assumed (at least in some species) to estimate fish growth because fish growth is directly proportional to otolith growth. However, some studies disprove a direct link between body growth and otolith growth. At times of lower or zero body growth the otolith continues to accrete leading some researchers to believe the direct link is to metabolism, not growth per se. Otoliths, unlike scales, do not reabsorb during times of decreased energy making it even more useful tool to age a fish. Fish never stop growing entirely, though growth rate in mature fish is reduced. Rings corresponding to later parts of the life cycle tend to be closer together as a result. Furthermore, a small percentage of otoliths in some species bear deformities over time.[17]

Age and growth studies of fish are important for understanding such things as timing and magnitude of spawning, recruitment and habitat use, larval and juvenile duration, and population age structure. Such knowledge is in turn important for designing appropriate fisheries management policies.

Diet research

Since the compounds in fish otoliths are resistant to digestion, they are found in the digestive tracts and scats of seabirds and piscivorous marine mammals, such as dolphins, seals, sea lions and walruses. Many fish can be identified to genus and species by their sagittal otoliths. Otoliths can therefore, to some extent, be used to reconstruct the prey composition of marine mammal and seabird diets.

Sagittal otoliths (sagittae) are bilaterally symmetrical, with each fish having one right and one left. Separating recovered otoliths into right and left, therefore, allows one to infer a minimum number of prey individuals ingested for a given fish species. Otolith size is also proportional to the length and weight of a fish. They can therefore be used to back-calculate prey size and biomass, useful when trying to estimate marine mammal prey consumption, and potential impacts on fish stocks.[18]

Otoliths cannot be used alone to reliably estimate cetacean or pinniped diets, however. They may suffer partial or complete erosion in the digestive tract, skewing measurements of prey number and biomass.[19] Species with fragile, easily digested otoliths may be underestimated in the diet. To address these biases, otolith correction factors have been developed through captive feeding experiments, in which seals are fed fish of known size, and the degree of otolith erosion is quantified for different prey taxa.[20]

The inclusion of fish vertebrae, jaw bones, teeth, and other informative skeletal elements improves prey identification and quantification over otolith analysis alone.[21] This is especially true for fish species with fragile otoliths, but other distinctive bones, such as Atlantic mackerel (*Scomber scombrus*), and Atlantic herring (*Clupea harengus*).[22]