Snapper otoliths and estimating age: Is there a better way?

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To have a good basis for understanding the health of a fished population, scientists need to study the age structures of the fish that are being landed. In some cases, this can be estimated from the size of the fish, but often size cannot tell you much about a fish's age because growth slows as age increases. For example, some fish species can have similar lengths and yet one can be 5–10 times older than the other.

Instead of using length, otoliths, also known as fish ear stones, are most often used to age bony fishes by counting layers or zones that represent annual growth, like layers or rings in a tree. Unfortunately, for many fish species it is often not as simple as counting tree rings because the layers in otoliths are complicated with ring splits and inconsistent spacing, and what you are counting may not be annual growth. This is why it is important to use a method to 'validate' the ages estimated from counting rings in the otoliths. But once you validate, do you need to count growth rings in every otolith from fish that are caught to keep track of the age of fish being landed? A recent study of cardinal snapper (*Pristipomoides macrophthalmus*) from the Caribbean has shed light on a different way to easily estimate age for deep-water fishes and here's how it worked.

How to read an otolith

Figure 1 is an example of how fish age can be estimated from an otolith. This otolith section from a cardinal snapper – cut across the growth layers to make it easier to count inside – can be interpreted in many ways. If you blur your vision and look at the image from a distance, you can see groupings of smaller zones that might be gathered together as one annual growth layer. This approach leads to age estimates that are maybe

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Fisher Mario David of Honduras with one of the older cardinal snappers (*Pristipomoides macrophthalmus*) from offshore of Guanaja, in the Bay Islands of Honduras of the Caribbean Sea. This fish, despite its age exceeding 60 years, had a length that was similar to other cardinal snappers that were much younger. Image: © Ivy Baremore, MarAlliance

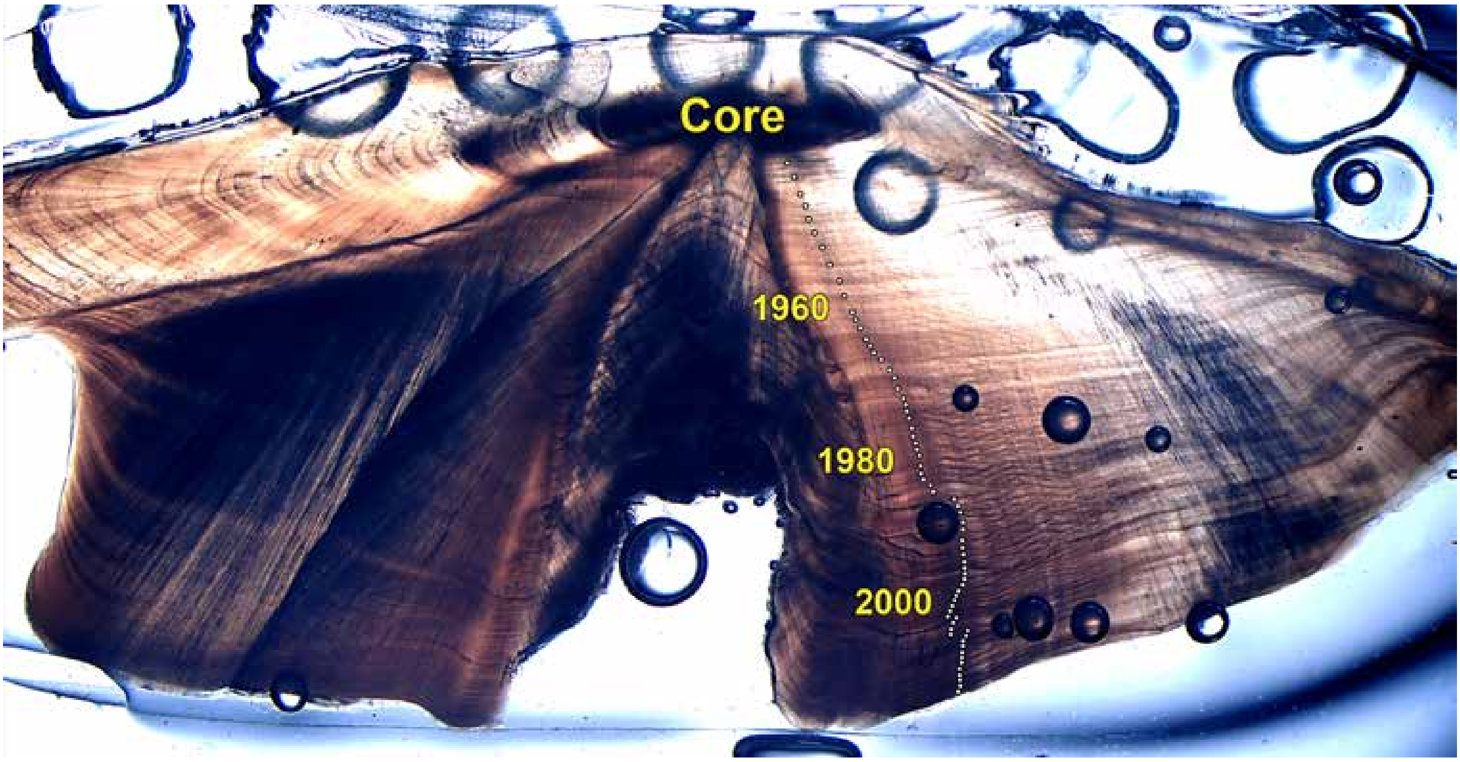

Figure 1. Otolith section image of the 68-year-old cardinal snapper that was validated with measurements of carbon-14 in the core or earliest otolith growth (Baremore et al. 2025). White dots mark the positions of presumed annual growth zones that were supported with a carbon-14 measurement in the otolith core. These growth zones can sometimes be quite difficult to identify and count accurately by eye. The years of formation are noted as a timeline in the otolith section ranging from the edge (capture year = 2019) to the core (hatch year = 1951). Image: © Virginia Shervette of University of South Carolina, Aiken

10–20 years old, but if you look closer at the finer growth layers it would be easy to get many times more, maybe even an age estimate approaching 100 years. So, which way of viewing this otolith for an age estimate is correct? In this image, we have marked the best way to estimate age for this approximately 68-year-old specimen. This approach has been validated by using another method to determine the age of a fish.

Bomb radiocarbon dating – A validation method

The testing of nuclear bombs in the 1950s and 1960s released radioactive elements (radioisotopes), causing numerous problems for people, locally and globally. These isotopes circulated the planet and have since been found in every living habitat on Earth. As a result, these elements have been used by scientists as tracers to help us understand chemical and biological pathways in marine ecosystems.

One such element is an isotope of carbon called radiocarbon (carbon-14, written as 14C). While this elemental isotope is not particularly dangerous to life, it has been naturally incorporated into living things, including you and me, and is often stored in calcified skeletal and non-skeletal structures, such as otoliths. As a result, the carbon-14 signal that was created by nuclear testing can be used as a time-specific marker, from the beginning of thermonuclear testing in 1952 (Ivy Mike[3]) until the Limited Test Ban Treaty was finally enacted in 1963. This signal can be seen graphically as a pulse that doubled the naturally occurring carbon-14 levels in the atmosphere over a period of just under 10 years. The levels have been declining at a steady rate from a peak in the mid-1960s and 1970s to the present day. Hence, if we can detect or measure this carbon-14 pulse in calcified growth structures, such as clam shells, coral or otoliths, then we can test our estimates of age from counting growth zones or layers by lining up the dates of formation.

3 Ivy Mike was the first thermonuclear test that employed nuclear fusion, as opposed to fission, to boost the power of nuclear explosions to exceed 1 megaton of TNT in energy equivalence. (https://en.wikipedia.org/wiki/Ivy_Mike).

Figure 2. The bomb pulse is shown here as a rise in carbon-14 levels during the late 1950s in the graph that overlays a photo of the first thermonuclear test (Operation Ivy Mike Shot at 10.4 megatons of TNT equivalency) in 1952. This depiction has opakapaka (*Pristipomoides filamentosus*) among the mushroom cloud as the first age-validated snapper species – up to ages that can exceed 40 years – of the Hawaiian Islands using this bomb carbon-14 signal. Illustration: Allen H. Andrews, SPC

Otolith mass-to-age correlation

In the case of cardinal snapper of the Caribbean, we validated the estimated age and growth of this species – as shown in Figure 1 in one of the largest otoliths that was aged to 68 years – using the bomb carbon-14 signal. This was already a groundbreaking result, putting the deepwater snapper among the oldest snapper species in the Atlantic Ocean. But we took this work a bit further considering that the species mostly lives in the Caribbean Sea, where fisheries managers are hard pressed to find funding for expensive age and growth analyses. Noting the large size of cardinal snapper otoliths and the steadily increasing weight, or mass, of the otoliths with fish size, and because otoliths continue to grow throughout the lifespan of each fish, we modelled the growth of the cardinal snapper otoliths with increasing age. The correlation of otolith mass-to-age was surprisingly high, and we found it could be used to predict the age of other cardinal snapper that were not aged using otolith sections. In fact, we found that while the otolith section age was quite difficult to determine for many of the otolith sections because the zones were not well defined, otolith mass was actually more reliable based on the age-validated cardinal snapper. Hence, we were able to apply this relationship to a broader dataset to describe the currently fished population with a growth curve, which is a crucial baseline and tool for long-term monitoring of the age structure of this fished population. This is important because older fish may produce more eggs that are potentially more capable of survival. There may also be environmental shifts that make successful reproduction episodic. Hence, long-lived fish would bridge the gaps in favourable oceanic conditions and could wait for the next time that recruitment would be successful.

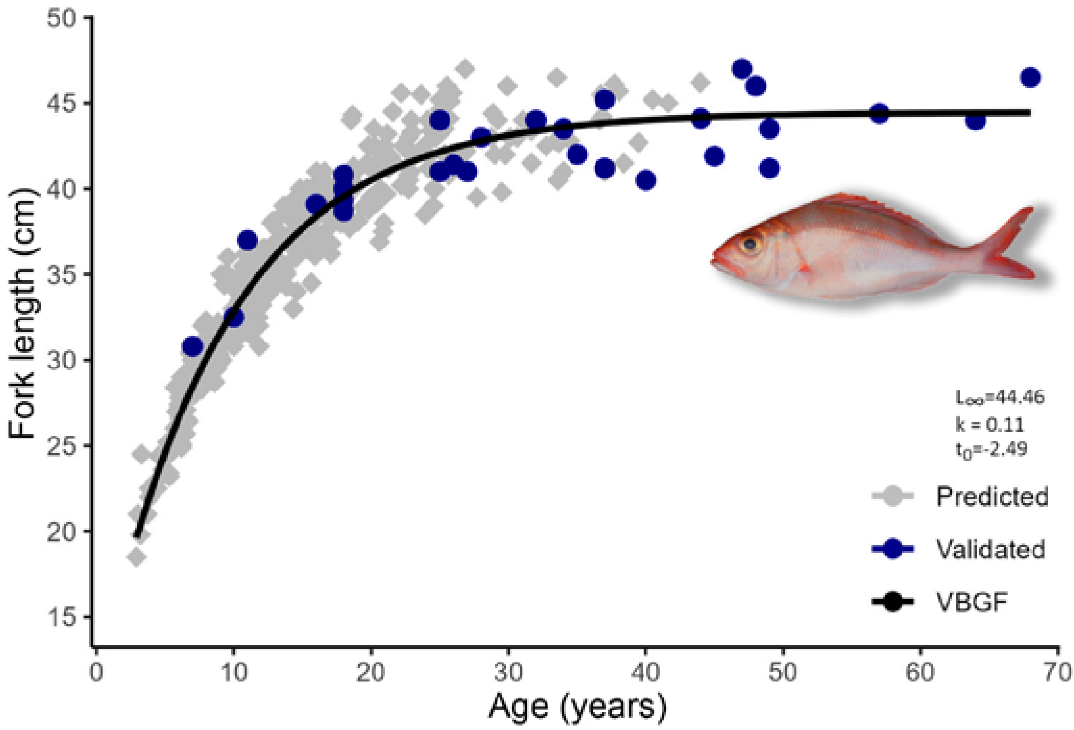

Figure 3 shows how cardinal snapper length (FL = fork length) changes with age and how growth slows as maximum size is approached. The validated fish were aged from the otolith sections (as shown above) along with support from the measured carbon-14 levels in the otolith. This information was combined as an otolith mass-to-age correlation that was used to reliably predict the age of fish that were not aged from counting growth zones in otolith sections. The curve is a von Bertalanffy growth function (VBGF) that is often used to describe how a species' growth is often connected to its reproductive characteristics in modelling population dynamics. Note that a fish near maximum length could be 20 years to more than 60 years of age. L_∞ = asymptotic length, k = growth coefficient, t_0 = theoretical fish length at age 0.

Can this support South Pacific snapper fisheries?

The findings for cardinal snapper of the Caribbean Sea reveal a promising avenue in establishing a low-cost method for monitoring regional deep-water snapper fisheries of the South Pacific. In some cases, there are existing age validation studies that set the stage for taking the next steps in making this method available in places where the expertise and long-term capacity for otolith age reading is difficult to maintain. For example, the opakapaka (*P. filamentosus*) (Figure 2) and onaga (*Etelis coruscans*) of the Hawaiian Islands, have been validated to live more than 40–50 years and it would not take much effort to explore otolith-based options with these species in the South Pacific. Other deep-water and reef fishes of the Pacific have also been shown to exhibit strong relationships of otolith mass-to-age but have not been taken much further than establishing the relationship. In some cases, the relation of otolith mass to fish length has been used to provide an initial indication of potential problems with age estimation by having a poorly defined or odd-looking curve. Because many of the island nations of the Pacific have fisheries resources that require assessment and regular monitoring, we suggest that otolith archives be canvassed for opportunities to establish such a baseline to assist with regional fisheries management.

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