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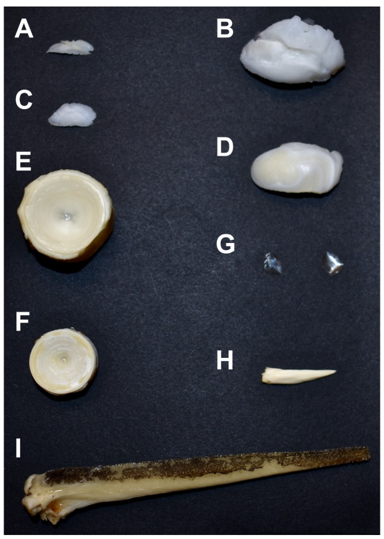
How old am I?

Above: A fisheries scientist removes an otolith from a large red snapper. Photos by David Hay Jones.

When you hear the word *aging*, what comes to mind? In day-to-day conversation, we use *aging* to describe the process of growing old. However, *aging* also means determining the age of something. In fact, aging fishes is one of the most important parts of fisheries science!

Why age fish?
Age data form the backbone of the modern stock assessment. By aging some of the fish from a given population, we gain insight into the proportions of different age classes in the population. We may also learn about migration patterns, changes in environmental requirements, and survival and mortality rates. Furthermore, we can combine age data with size data (e.g. length) in mathematical models to evaluate growth, which indicates resource use and the effectiveness of our management strategies. Clearly, age data are integral to successful fisheries management. Below, we describe the three steps necessary for aging fish.



Left: Here's an assortment of aging structures: otoliths from A) crevalle jack, B) red snapper, C) tripletail, and D) red drum; vertebrae from E) great hammerhead and F) blacktip shark; G) scales from Gulf menhaden; and first dorsal spines from H) tripletail and I) gray triggerfish.

Step 1*: *Choose the structure(s)
The first step of the aging process involves choosing the appropriate hardpart(s) (bony or calcified structure(s) from the fish's body) to use. We may consider various structures depending on the species of interest, but we must ultimately select a structure that deposits material throughout the fish's life, leaving annual rings inside the structure (just like a tree trunk). Here are some examples of structures that may be used for aging:

Scales – Historically, scales were the most popular structure for aging. They have been used for this purpose since the late 1800s. Scales are easily extracted from live fish without sacrificing the animal and they are easily prepared for aging. However, the annual rings within scales may be difficult to interpret. Also, rings from the early years of a fish's life may erode or disappear entirely, which can cause us to underestimate age. Therefore, we use scales for aging primarily short-lived species (e.g. Gulf menhaden, which have a maximum age of 6 years).

Otoliths – "Otolith" means "ear-stone." Each fish has a pair of otoliths, one in each inner ear. Actually, all vertebrates – including humans – have otoliths. The primary function of otoliths in living organisms is to assist with hearing and balance. Otoliths are "calcified" (made of a chemical compound called calcium carbonate, instead of true bone), and their size and shape vary by species. Extracting otoliths always requires sacrificing the fish, and preparing otoliths for aging can be time-intensive. Sometimes, otoliths lack growth rings or are exceedingly delicate to handle or difficult to extract. Despite these drawbacks, otoliths are the most common structure used for aging fish. Examples of fishes aged with otoliths include snapper, grouper, and drum.

Fin spines and rays – Like scales, fin spines and rays can be extracted from live fish without the need for sacrifice. However, early-life growth rings in spines and rays sometimes shrink and/or vanish. This (among other factors like "false" rings) can make the growth rings within spines and rays challenging to interpret. Examples of fishes aged with spines and rays include tuna, swordfish, triggerfish, and tripletail.

Vertebrae – The typical aging methods for bony fishes do not work for elasmobranchs (sharks, skates, and rays) because they lack true bone. Fortunately, elasmobranch vertebrae contain mineralized calcium phosphate, making them useful for aging. Examples of elasmobranch species aged with vertebrae include finetooth shark, blacktip shark, and butterfly ray.

Step 2: Prepare the structure(s)

Scales – Scales often curl as they dry, which makes them difficult to age. To address this issue, we can a) place the scales between glass microscope slides, then tape the slides together, or b) make impressions of the scales using a tool called a scale press. Both methods result in microscope slides with flattened scales or scale impressions, ready for aging.

Otoliths – Preparation of otoliths varies depending on the size and shape of the otoliths. If an otolith is relatively small and thin, and we can see the rings inside the otolith just by looking at the outside of the otolith, we may be able to age the otolith whole. This method requires little to no preparation. However, if an otolith is large or thick and we cannot see inside the otolith, we must obtain a thin cross-section from the center of the otolith using a thin section grinder or a low-speed saw. We then adhere the otolith sections to microscope slides for aging.

Fin spines and rays – Like large/thick otoliths, these structures are too dense to be aged whole, so we section them using a thin section grinder or low-speed saw and adhere the sections to microscope slides for aging.

Vertebrae – We section vertebrae using a low-speed saw and adhere the sections to microscope slides for aging.

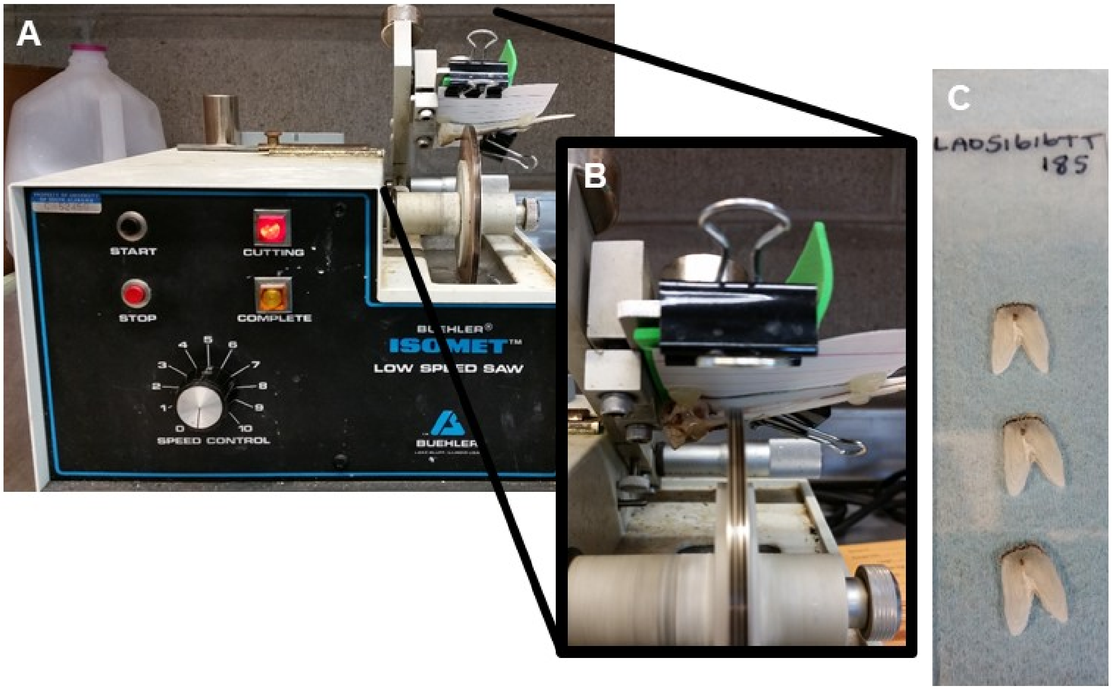
Step 3: Age the structure(s)

Once we've adequately prepared the aging structure(s) as described above, we examine the structure(s) under a microscope to magnify the alternating clear and opaque rings. In otoliths, the clear rings represent periods of fast (summer) growth and the opaque rings represent slow (winter) growth. This pattern may be reversed in other structures, but regardless, a clear ring plus its adjacent opaque ring typically represent one year of growth. We count the pairs of clear and opaque rings to assign an age, in years, to each structure. Typically, two people ("readers") *blindly* age the entire set of structures in the study (i.e. without knowing the other reader's assigned ages). Then, the readers compare their sets of ages to ensure that agreement is high. Once the readers address any disagreements and develop a set of agreed-upon final ages, the data are ready to be used in age and growth analyses and stock assessments.

Gray triggerfish

Why age gray triggerfish?

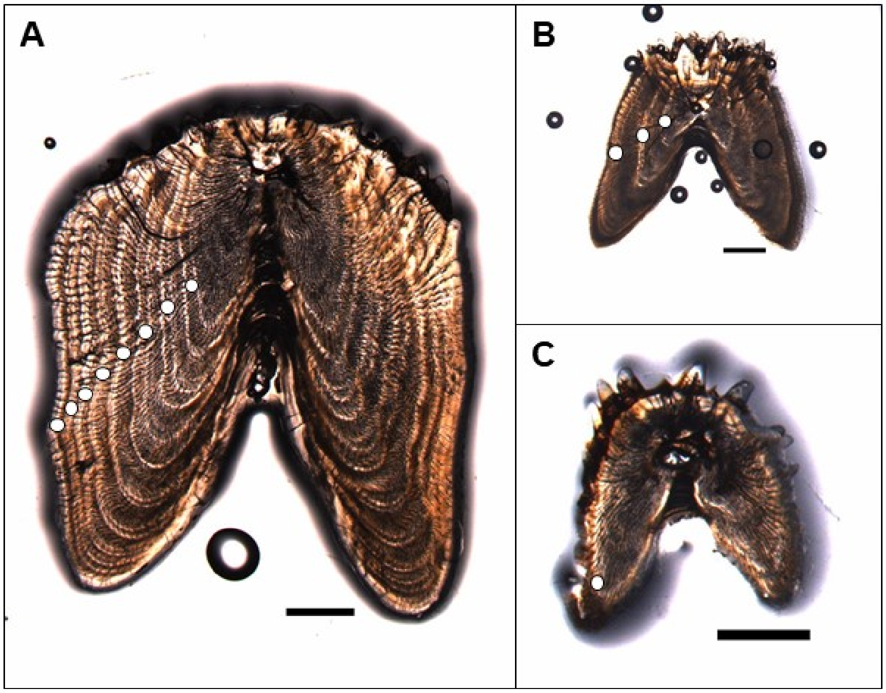
The Gulf of Mexico gray triggerfish fishery is dominated by recreational landings. Following the overexploitation of traditionally targeted reef fishes like red snapper, gray triggerfish, which were once considered "trash fish," experienced a rapid increase in popularity among recreational anglers during the late 1980s and 1990s. Unfortunately, this shift led to overfishing (an unsustainable rate of removal) and an overfished stock status (too few fish). Scientists depend upon up-to-date, sex-specific age and growth data to accurately assess the health of the stock and ensure the sustainability of the stock. However, the most recent assessment, conducted in 2015, noted a lack of such data.



Above: Our low-speed saw (A) is outfitted with four consecutive blades (B) to produce three sections from each spine (C).

How did we help?

We recently completed a study investigating the age and growth of a specific population of Gulf of Mexico gray triggerfish. We began by collecting gray triggerfish from the Alabama Artificial Reef Zone (AARZ), a recreational fishing hotspot off the coast of Alabama. Since gray triggerfish otoliths do not contain reliable annual growth rings, we used the first dorsal spine (the large, bony spine at the front of the dorsal fin) for aging purposes. After extracting and cleaning the spines, we sectioned them using a low-speed saw. Gray triggerfish spines are challenging to age, so we took three consecutive sections from each spine. This gave us multiple views of the growth rings, which helped us immensely during the aging process.



Above: Here are images of gray triggerfish spine sections as viewed through a microscope for A) an 8-year-old fish, B) a 3-year-old fish, and C) a 1-year-old fish. The white circles on each image represent annual growth rings, and the black bar represents 1 mm.

What did we find?

The oldest male in our study was 10 years old and the oldest female in our study was 9 years old. Previous Gulf of Mexico gray triggerfish studies have reported maximum ages from 9 to 14 years. Our lower maximum age is likely due to elevated fishing pressure in the AARZ compared to the rest of the Gulf. Fishing pressure causes older, larger fish to be preferentially caught and removed, while younger, smaller ones are left in the water.

We paired our size and age data in mathematical models of growth to learn more about the growth patterns of AARZ gray triggerfish. The models showed that growth plateaus around age 4, and legal-size gray triggerfish (at least 15 inches for the recreational sector) are at least 2 years old. The models also indicated, in agreement with previous studies, that male gray triggerfish generally grow larger than females. This makes sense considering the unique reproductive strategies of gray triggerfish. During spawning (the summer months), males are responsible for building and defending nests, as well as maintaining a harem of females. Clearly, larger males are better equipped for these roles compared to smaller males.

Our findings enhance our knowledge of the age and growth of Gulf of Mexico gray triggerfish. Additionally, our study provides an important source of data for the ongoing Gulf of Mexico gray triggerfish assessment, which is scheduled for completion in early 2020.

Finetooth shark

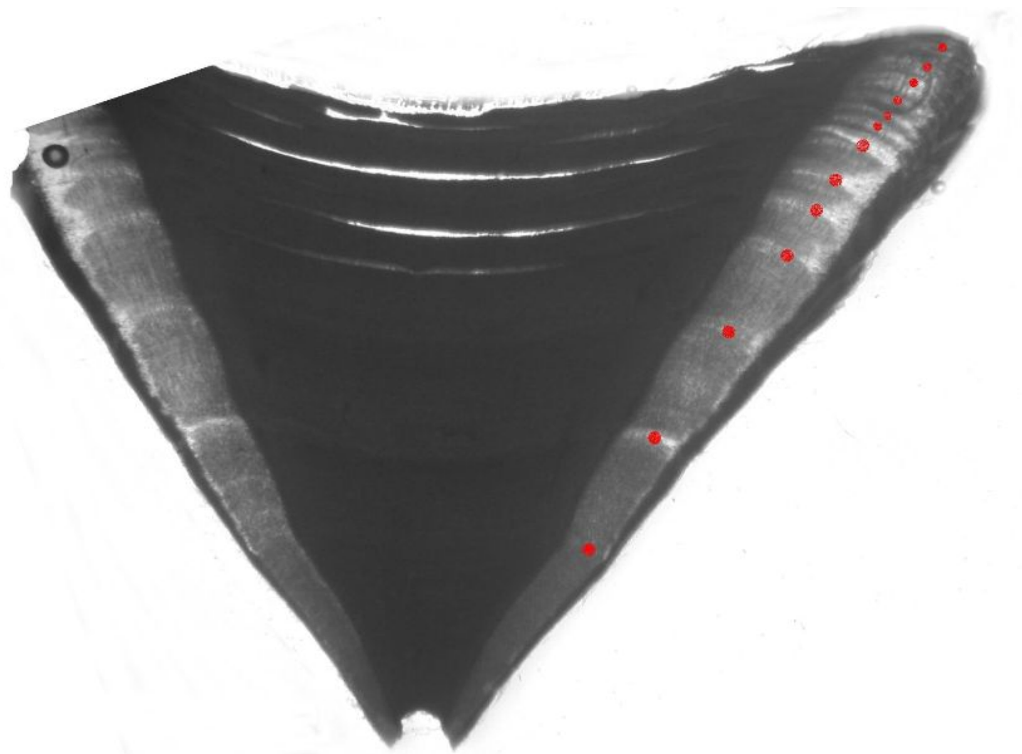
Above: An adult female finetooth shark

Why age sharks?

Understanding the age and growth of sharks is important for management and conservation purposes. Sharks are generally slow-growing and long-lived, with multiple, complicated modes of reproduction. By determining their life history characteristics, such as size at sexual maturity, maximum age, and growth rates, scientists can provide counsel for appropriate management and conservation practices. Many shark stocks in the Gulf of Mexico are reviewed by SEDAR (SouthEast Data, Assessment, and Review), a cooperative fishery management process. A SEDAR panel uses biological information and catch data from researchers and state agencies to assess the health of each stock. For example, the most recent SEDAR for the Atlantic sharpnose shark, the most common shark in the Gulf of Mexico, used age and growth data to determine that this stock is not overfished and is not currently undergoing overfishing.

How can we age sharks?

Unlike their bony fish relatives, sharks lack bones, meaning we can't use things like otoliths to age them. Some species of shark, like spiny dogfish, have dorsal fin spines that can be used for aging (similar to the process described above for triggerfish). However, most shark species do not possess dorsal spines. The next hardest part of a shark's body is the vertebrae. As with otoliths and spines of bony fish, sharks build a new concentric pair of opaque and translucent vertebral bands each year. We can cross-section individual vertebrae and count the bands to estimate each shark's age.



Above: Here's an image of a thin section through the vertebrae of a finetooth shark. Each red circle denotes a band pair; in other words, this finetooth shark was 13 years old.

What species of sharks have been aged in the Gulf of Mexico?

In the northern Gulf of Mexico, many age and growth studies have been conducted on several shark species, including Atlantic sharpnose sharks, blacknose sharks, finetooth sharks, great hammerheads, and blacktip sharks. Smaller shark species, like Atlantic sharpnose sharks, mature around 2 years for males and 2.5 years for females with a maximum age of approximately 18 years. A larger shark species, the blacktip shark, only lives up to 16 years, but matures around 4 years for males and 6 years for females.

How long do sharks live?

In general, sharks are long-lived fishes. In 2016, a group of scientists investigated the age of the Greenland shark, a slow-growing, Arctic species. Because Greenland sharks live in cold water, their vertebrae do not calcify in the same manner as sharks in warmer climates. Therefore, scientists were unable to use vertebrae to age this species. Instead, the team examined eye lenses from the Greenland sharks, which contain proteins that are metabolically inactive, meaning that they do not change over each shark's lifespan. Using a process known as radiocarbon dating to examine these proteins, they were able to estimate that a Greenland shark could live anywhere from 272 to 512 years old, making the Greenland shark the oldest known vertebrate on Earth! Check out the original article here.

Smooth butterfly ray

Above: A mature female smooth butterfly ray

What are butterfly rays?

Butterfly rays are a family of marine stingrays known for their short tails and large distinct pectoral fins (or "wings"), which give them a butterfly-like shape. These rays have a unique feeding strategy: they use their pectoral fins to strike live fish prey, which stuns the fish and allows the ray to consume the fish whole. Some species of butterfly ray are very large; for example, the spiny butterfly ray on the Atlantic coast can grow to more than 7 feet wide and over 100 pounds. The smooth butterfly ray is common in the northern Gulf of Mexico and can grow to 3 feet wide and almost 20 pounds. Smooth butterfly rays are not often seen by the public because they are rarely caught with hook and line; however, they are frequently caught as bycatch in the commercial shrimp fishery.

How can we age butterfly rays?

Given their voracious appetite, high abundance, and inclination to being caught in shrimp trawls, understanding how fast and old butterfly rays grow is important from an ecological perspective. To age sharks and rays, scientists typically section the centra (a large portion of the vertebra, as shown above) and look for the growth bands, as was described for the finetooth shark above. Unfortunately, the centra of butterfly rays are very small, and unlike most elasmobranchs, lack visible growth bands. Therefore, butterfly rays cannot be aged using traditional methods. Recently, Dr. Kristene Parsons of the Virginia Institute of Marine Science and the Bimini Biological Field Station successfully aged spiny butterfly rays by scanning the rays' centra using high-resolution X-ray computed tomography (HRXCT). Dr. Parsons found that spiny butterfly rays are fast-growing, with females growing to greater than 4 feet wide in less than 3 years. The oldest individual in her study was a 7 foot wide, 18 year-old female.

Can we use HRXCT to age Gulf of Mexico smooth butterfly rays?

We recently attempted to age smooth butterfly rays using Dr. Parsons' HRXCT protocol. However, the centra of the smooth butterfly rays were simply too small to age. Because aging the smooth butterfly ray using hard parts is presently impossible, we turned to a type of analysis called cohort analysis.

Cohort analysis involves grouping individuals, based on length, into distinct age "cohorts", where each cohort consists of individuals of the same age. (*Imagine if all people were born on the same day every year, allowing us to estimate a young child's age based on their height*). Once we establish cohorts, we can follow how the cohort grows over time, as individuals in the cohort increase in size at similar rates. Since cohort analysis relies on size, it is generally only useful for the first year or two of growth, given that cohorts begin to overlap in length as individual growth plateaus. Despite this, cohort analysis can provide useful insight into juvenile growth rates, mortality rates, age at sexual maturity, and recruitment (the number of juveniles that reach maturity).

By using cohort analysis to investigate growth of the smooth butterfly ray, we found that individuals are fast-growing and reach sexual maturity after just one year, which is uncommon among elasmobranchs. Although the general population trend for the smooth butterfly ray in the northern Gulf of Mexico is unknown, their ability to quickly reach sexual maturity informs us that the species can most likely withstand moderate exploitation, such as being caught as bycatch in the commercial shrimp fishery.

Sea of Acronyms

Being an informed angler begins with understanding the terminology used in fisheries management. This series helps demystify the concepts hidden beneath a sea of acronyms.

APE

Average Percent Error

In the context of age and growth studies, APE is a relative indicator of precision within and between the two readers

Marine Fisheries Ecology Lab

I'm Marcus Drymon, an Assistant Extension Professor at Mississippi State University and a Marine Fisheries Specialist at Mississippi-Alabama Sea Grant. Emily Seubert, Amanda Jefferson, Matthew Jargowsky, and I comprise the Marine Fisheries Ecology Lab. We'd love to hear from you! Please reach out to us at marinefisheriesecology@gmail.com

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