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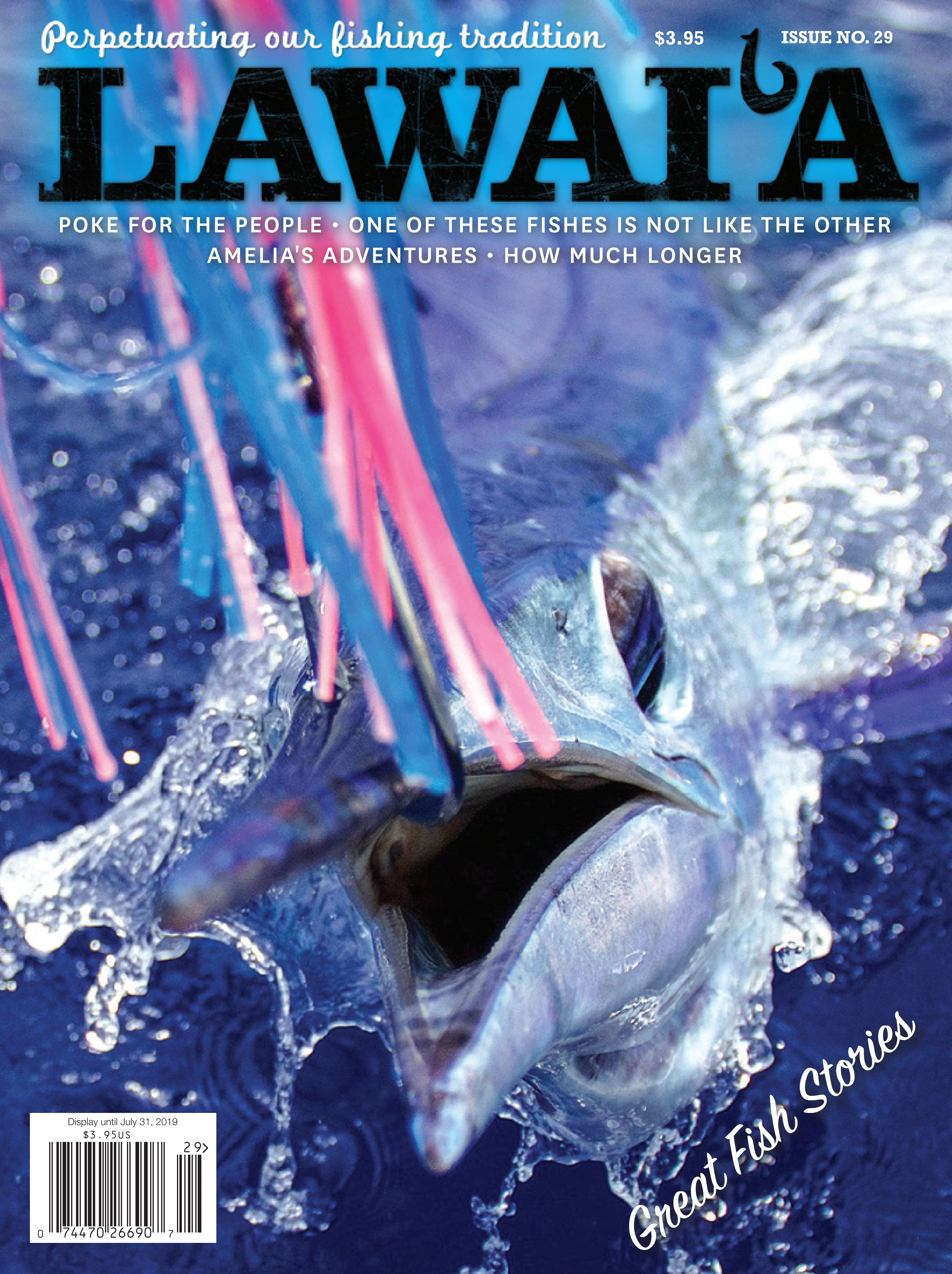

Great Fish Stories

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ONE OF THESE FISHES IS NOT LIKE THE OTHERS

HAPU'UPU'U HAS A LONG AND COMPLICATED LIFE HISTORY

Photo courtesy: Edward DeMartini, 2007

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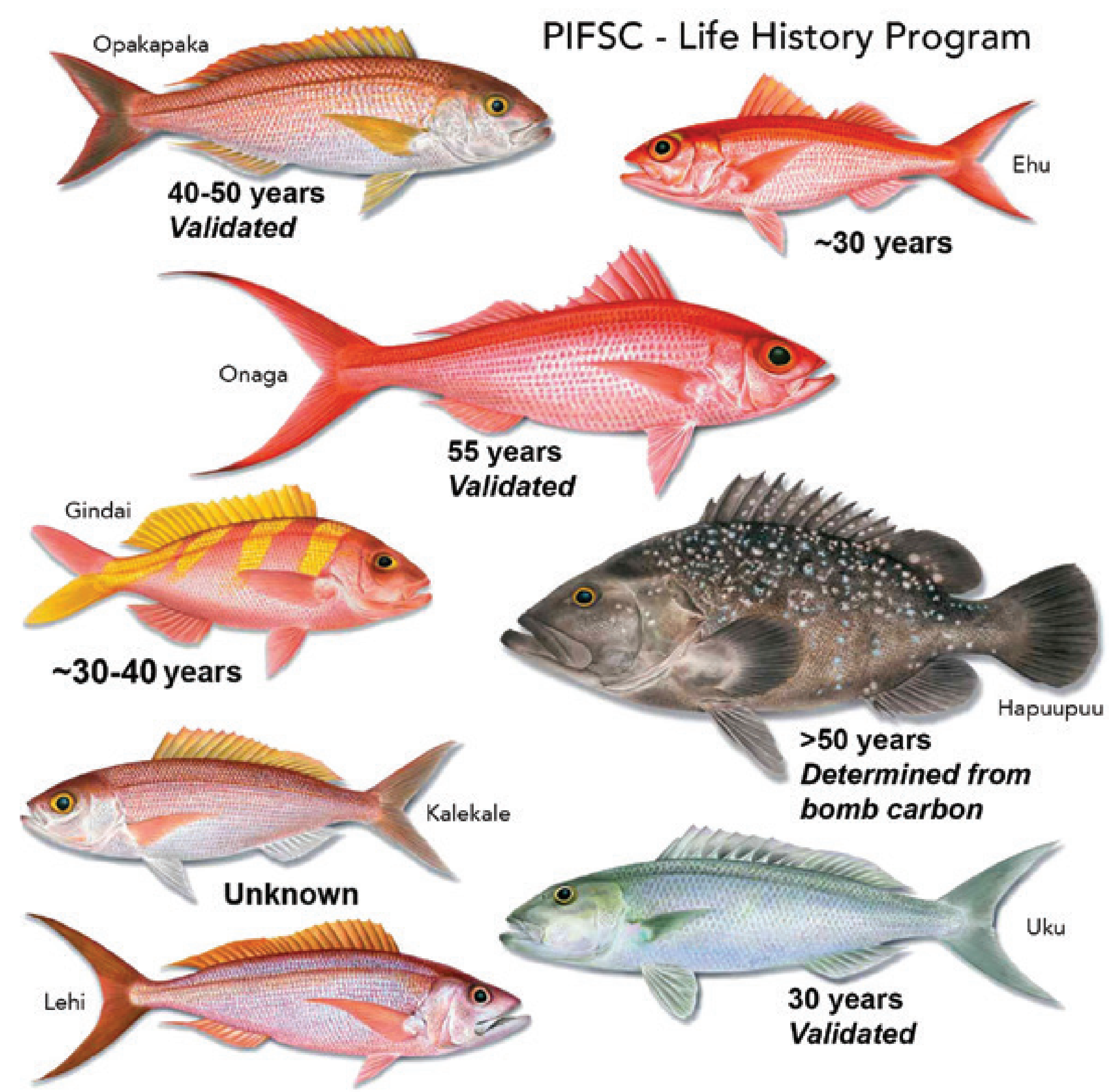
An uncommon photograph of a hapu'upu'u (Hyporthodus quernus) at a depth of 10-15 m at Midway Atoll (previous page). In the main Hawaiian Islands, hapu'upu'u are typically found much deeper. Coral sand can be seen on the body and is likely a result of living and feeding in and near caves on the reef.

Most fishermen in the Hawaiian Islands are familiar with the endemic Hawaiian grouper or hapu'upu'u (Hyporthodus quernus) as a favorite food fish. Few grouper species are found in the Hawaiian Islands and hapu'upu'u is the largest that is a regular part of the local fishery. In the past, a larger species (giant sea bass, Epinephelus lanceolatus) has been landed and can also be called hapu'upu'u, but this fish was probably never present in great numbers and could attain a much larger size (exceeding 6 feet and 500 lbs.). The hapu'upu'u associated with the bottomfish fishery rarely reaches a size of 3 feet but can weigh up to 70 lbs (see 2017 landing in Hawaii Fishing News by Kevin Shiraki). It has been fished for many years, but little was known about its biology. Hapu'upu'u has been managed as part of a group called the Deep 7, a mix of 6 snappers and hapu'upu'u. A potential issue with this approach is that hapu'upu'u are not like snapper in many obvious ways and recent work on its age, growth, and maturity revealed even more differences associated with its life history.

Illustrations of the Deep 7 group (below) with one additional species (Uku) commonly caught in the Hawaii bottomfish fishery. Estimated and validated longevity are provided for most of the species, with age not known for kalekale and lehi. Validated ages were determined with bomb radiocarbon (14C) dating studies performed by the Life History Program at

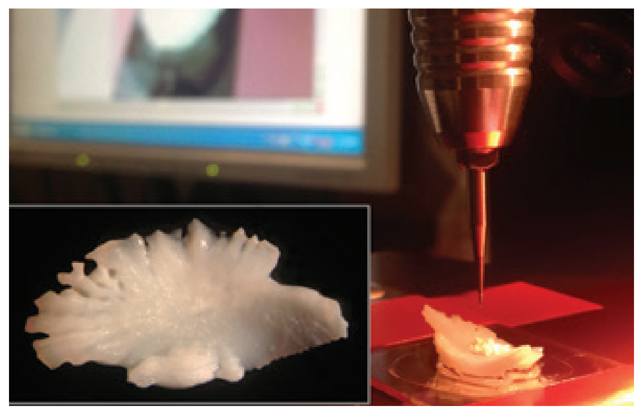


the Pacific Islands Fisheries Science Center of NOAA Fisheries. Fish illustrations were modified from a Bottom Fishes of Hawaii poster produced by the Education Program of the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii.

Hapu'upu'u have been aged using the usual method of looking for growth zones in the otoliths (ear stones) and then making assumptions about what the growth zones represent. For many species, the growth rings or zones seen in otoliths are fairly easy to count and they actually do represent one year of growth per zone, much like the rings you see in some trees. However, the ring 'pattern' is not always straight-forward, hence, it is necessary to make sure that the zone being counted is formed once per year by validating the periodicity with some kind of reference clock. As it turns out, there is another clock in the ear of fishes and it is held within the chemistry of the otolith itself — otoliths store a chemical record of the marine environment where ever the fish lived throughout its lifespan.

Shown (top) is a cross section of a hapu'upu'u otolith that was used to estimate age from growth zone counting but was also used for bomb radiocarbon dating. The earliest growth is at the top middle of the section where the core (birth year material) was extracted with a milling machine for radiocarbon analysis. Notice that the zone structure is quite confusing as you count from the core to the lower edges (arrows indicate growth direction), with numerous changes to the pattern that you may or may not choose to count. Can you find enough growth zones to add up to the bomb carbon age of 49 years for this fish?

Hapu'upu'u have large otoliths that can exceed 1 gram (0.035 oz.) of calcium carbonate (~50 grains of uncooked white rice). Compared to most fishes, this represents a great amount



of material and a cross section of the otolith should reveal growth zones that can be counted. However, early studies of hapu'upu'u otoliths revealed that the growth zone pattern was very complicated and quite difficult to count. The zones often split, rejoin, or disappear depending on where you count in the otolith cross section. Hence, when age readers finally developed a growth curve for hapu'upu'u using otolith growth zones counts from a group of fish (small to large), the range of size-at-age was complicated and difficult to imagine as a true representation of fish growth. It is because of this difficulty that the use of a method called bomb radiocarbon dating was necessary to independently derive ages for hapu'upu'u.

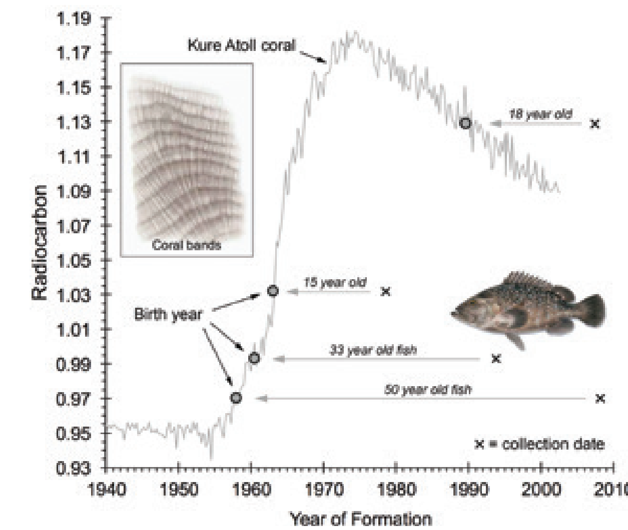
Pictured (above) is the computer-controlled micromill used to remove the birth year material from the center of the hapu'upu'u otolith (inset picture showing some of the concentric growth structure of the whole otolith). The mill uses a very small dentist drill bit to extract the small pile of white powder seen on the surface of the mounted otolith. This powder is used for the bomb radiocarbon analysis.

Bomb radiocarbon dating is a method that uses a radioactive signal that was created by nuclear bombs in the 1950s and 1960s. This signal happened a long time ago, but it is still present in the ocean and it is stored in anything that grows a skeleton. The best records are from reef building corals where we already know the growth rate is approximately 1 cm per year. Therefore, when we drill into a coral to remove a sample that is called a coral core (like drilling into a tree with a coring device), the bands we see in the core can be dated and the ocean chemistry for those dates can be measured and used as a time reference. This radiocarbon signal was strongest up to around 1970–1980, after which the signal declined because we as humans insisted that governments stop nuclear testing in the atmosphere (1963 Nuclear Test Ban Treaty) — the signal in ocean waters is lagged behind the atmosphere by about 10 years because of air-sea mixing. Perhaps the only good thing about the nuclear testing was that we can use this signal to figure out how long fish can live.

To use this approach, the chemistry of the otolith needs to be lined up with the coral records. It turns out that otoliths and corals record the same radiocarbon signal through time, but they both need to be from the same area because globally the timing of the signal can vary. In Hawaii, we have several coral records like this that specify the radiocarbon levels from recent times back to and before the 1950s; hence, the oldest part (birth year) of the otolith can be extracted to measure radiocarbon, align the measurement with the coral radiocarbon record, and as a result we can determine the birth year and age of the fish.

Diagram (above right) showing the rise of bomb-produced radiocarbon over time as it was recorded by a coral record at Kure Atoll (inset shows coral bands that represent annual growth, like a tree). Plotted with this coral record are the measured radiocarbon values from core (birth year) otolith material from four adult hapu'upu'u collected at different times (from the 1970s to 2000s). The X represents the fishing capture or collection date for each fish. Follow each horizontal arrow back in time to align the fish otolith radiocarbon value with the coral radiocarbon reference record — this reveals the birth year of each fish. The age of these hapu'upu'u is simply the difference between the collection date and the birth year from the coral radiocarbon record.

After analyzing the radiocarbon in otolith cores from the smallest to largest hapu'upu'u, we determined that they can live more than 50 years — possibly as high as 76 years — adding to their complicated life history. This species is what fish scientists call a "monandric protogynous hermaphrodite" (an organism that always matures first as a female, but later can change into a male, although it is likely that not all indi-



viduals change sex). Even though length at sexual maturity and sex change had been described previously, the age at which these stages occur was unknown and the latter is an important factor for understanding population growth. From observations of the female length at maturity (23 inches), female hapu'upu'u mature at an age of 10 years and change sex from female to male much later in life. The length at which males begin to appear in the population has averaged 35 inches, which is equal to 32 years. To be clear, fish smaller than this can become males, but of the hapu'upu'u included in this study (>50 fish), no male fish was less than 31 inches long and 34 years of age.

Now that hapu'upu'u have been shown to mature and sex-change at large sizes and old ages, these important biological factors could be used to quantify their differences from the other Deep 7 species. While the age, growth and maturity of most of the snappers in the group are not well known, it is certain that the life history characteristics are vastly different from hapu'upu'u — snapper are not sex changers and are likely to mature at a smaller size and earlier age. Opakapaka (Pristipomoides filamentosus), as an example of one species from the Deep 7 for which life history is well-known, grow rapidly and mature at a length of 16 inches, which equates to an age of just 3–4 years. Therefore, the slow growth and great longevity, late age at maturity, and complicated reproductive biology of hapu'upu'u distinguish it from the snappers of the Deep-7 bottomfish group.

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