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Bomb radiocarbon dating and estimated longevity of Giant Sea Bass (*Stereolepis gigas*)

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Abstract.—In January 2010, a massive giant sea bass (500 lbs, 227 kg; near maximum reported size of 557 lbs, 253 kg) was captured off Santa Cruz Island by commercial gill-netters. This specimen presented a unique opportunity to estimate and validate of the potential longevity of the largest nearshore teleost of the northeastern Pacific. A transverse section of the sagittal otolith produced consistent counts of 62 opaque annuli along two different axes of the ventral sulcus region, translating into an estimated birth year of 1948. This age estimate was supported by measurements of radiocarbon (^{14}C) in the other sagittal otolith core (within the first year of growth), relative to Δ^{14}C reference records used for bomb radiocarbon dating. Two otolith core samples produced Δ^{14}C values that were classified as pre-bomb (prior to ~1958–59), indicating a minimum lifespan of 51 years. It is likely that giant sea bass can live more than 60 or 70 years based on growth zone counts, but there is no evidence in the literature or this study to support longevity of 100 years.

Introduction

The Giant sea bass (*Stereolepis gigas*) is the largest nearshore teleost inhabiting coastal waters of Southern California and Baja California, Mexico, yet much of its life history is not well know (Miller and Lea 1976). The species is a grouper-like member of the wreckfish family (Polyprionidae; Shane et al. 1996) and occur from Humboldt Bay in northern California, south along the west coast of North America to the tip of Baja California, and into the Gulf of California (Eschmeyer et al. 1983). It rarely occurs north of Point Conception and was once common in the Southern California Bight (SCB; Crooke 1992). Giant sea bass are apex predators and represent the only resident fish "megacarnivore" in the California kelp bed community (Horn and Ferry-Graham 2006). It has been an important target of commercial and recreational fishing since the late 1800s (Figure 1) and attains a maximum reported length of 7′ 5″ (2.26 m TL) and a weight of 557 pounds (253 kg; Fitch and Lavenberg 1971, Eschmeyer et al. 1983). Commercial fishing of giant sea bass began in California waters, but shifted south of the US border as the population numbers in the SCB declined after 1936 when massive fish became rare in catches (Crooke 1992). The lack of life history information for giant sea bass is likely a result of the practice of dressing-out (beheading and eviscerating) fish prior to landing to conserve space on fishing vessels (Crooke 1992). This practice is unfortunate for scientists because, in addition to losing data on actual fish size, the lost head and entrails contain the structures most useful in life history studies – gonads for size-at-maturity estimation and (key to this study) otoliths for studying age and growth.

Fig. 1. A world record (428 pound) giant sea bass (*Stereolepis gigas*) caught by John T. Perkins off Catalina Island, CA in June 1905 in the years prior to the fishery collapse for this apex predator off California in 1936.

Despite its importance as a fishery and its huge size, the estimated lifespan of this species has not been rigorously evaluated.

In response to greatly depressed population levels, legislation was enacted to protect the fishery. In 1982 the California State Legislature banned the commercial fishing of giant sea bass in California waters, with the caveat of allowing commercial gill-netters to take one giant sea bass per trip. In addition, the California Fish and Game Commission banned recreational landings from California in 1982, while allowing anglers to capture two fish per trip from Mexican waters on long-range expeditions from California (Crooke 1992). In 1994, restrictions on gill and trammel netting increased protection for the species by banning this kind of fishing in state waters (within 3 miles of the mainland and 1 mile of the islands) in the SCB (California State Proposition 132). This proposition, known as The Marine Resources Protection Act, also implemented fishing depth restrictions off several mainland counties and around the Channel Islands. Most recently, concerns over sustained population viability led to the International Union for Conservation of Nature (IUCN) red listing the giant sea bass as a "Critically Endangered" species (Musick et al. 2000, Cornish 2004). The measures taken to protect this species appear to have been effective because the number of juvenile giant sea bass being reported as caught and released is increasing (Baldwin and Keiser 2008), and it is one of the five species of large near shore predators reported as returning to the SCB (Pondella and Allen 2008).

Much of the biological information available for giant sea bass is contained in the writings of the late California Fish and Game biologist, John E. Fitch (1918–1982). While much of the age and growth information is unique, the details of how these estimates were derived are either lacking or not thoroughly described. The oldest age estimated using otoliths is 72 to 75 years for a giant sea bass weighing 435 pounds (197 kg; Fitch 1965). In contrast, a larger fish, a beached 7-foot specimen weighing 539 pounds (244 kg) from San Clemente in 1963, was reported to be about 60 years old based on otolith ring counts (Fitch 1965). In addition, an estimate of approximately 50 years was provided for a medium sized fish (320 lb; 145 kg) with no derivation details (Fitch and Lavenberg 1971). The language from these sources, and the methods in use at the time, imply that surface reading of whole otoliths was used to estimate age. This perception was confirmed, coupled with the use of otolith clearing agents, by a researcher familiar with the laboratory practices of these researchers at the time (G.M. Cailliet, Moss Landing Marine Laboratories, personal communication). A longevity estimate of 90 to 100 years has been uncritically listed in some sources of life history information (e.g. Shanks and Eckert 2005). The origin of this estimate is speculatively based on a 557 pound (253 kg) fish caught in 1962, even though and it was clearly stated that there is "no reliable information to support such a theory" (Fitch and Lavenberg 1971). To date, there are no validated age data to support any conclusions about the longevity of this species.

There are few other data on growth and estimates of age at maturity in giant sea bass. Early age and growth is reported as 7 inches at age 1 year and twice this length at age 2 years (Fitch and Lavenberg 1971). Fitch and Lavenberg (1971) also mention an estimated age of 11 to 13 years at sexual maturity. This is similar to a reported age-at-maturity of 11 years for all giant sea bass, but there is a conflict from the observation by Domeier (2001) that "most fish" were mature at 7 to 8 years. In addition, age estimates reported for small to medium sized fish are 6 years at 30 pounds (14 kg), 10 years at 100 pounds (45 kg), and 15 years at 150 pounds (68 kg), but details of the age estimation method were not provided (Domeier 2001). A complete ageing study of giant sea bass at this time is unlikely due to their depressed population numbers and protected status, but questions of longevity can be answered with the application of bomb radiocarbon dating, a unique tool in estimating valid fish age.

Because age validation can be difficult for deepwater and long-lived fishes, bomb radiocarbon dating has evolved as a unique application aimed at addressing these issues (Campana 2001). The approach relies on a conserved record of the rapid increase in radiocarbon that occurred in the oceans of the world as a result of atmospheric testing of thermonuclear devices in the 1950s and 1960s (Broecker and Peng 1982). The uptake of bomb-produced radiocarbon by the marine environment, reported as delta carbon-14 ($\Delta^{14}C$) with reference to an established pre-nuclear radiocarbon record (Stuiver and Polach 1977), was virtually synchronous in the mixed layer of mid-latitude oceans and this signal was first recorded from marine carbonates in hermatypic corals (Druffel and Linick 1978). This time-specific signal provides a reference period that can be used to determine age. The application of bomb radiocarbon dating to fishes began with an innovative comparison of $\Delta^{14}C$ values recorded in otolith carbonate (core material) relative to regional $\Delta^{14}C$ records from hermatypic corals of the Great Barrier Reef (Kalish 1993). In this and other studies, measured $\Delta^{14}C$ levels provided an independent determination of age for validation of age estimates from growth zone counting in otoliths (Campana 1997; Kalish et al. 2001, Piner and Wischiowski 2004). Bomb radiocarbon dating has since been applied successfully to the otoliths of many species of teleost fishes, some of which are deep-water species with larval or juvenile phases in the mixed-layer, to validate estimated age (e.g. Andrews et al. 2007; Ewing et al. 2007; Neilson and Campana 2008). Of paramount importance for a successful application of bomb radiocarbon dating is the assembly of a suitable $\Delta^{14}C$ reference chronology from the region.

The goals of this study were to estimate the age of a massive giant sea bass specimen based on visual counts of growth zones in a thin-sectioned otolith and to validate this age estimate with bomb radiocarbon dating. It was hypothesized that a transverse otolith section would reveal growth zones (annuli) whose counts would represent putative age in years. To provide a validation of the age estimate, it was further hypothesized that bomb radiocarbon dating could be performed by: 1) assembling a regional $\Delta^{14}C$ reference chronology; and 2) measuring $\Delta^{14}C$ in the otolith core (within the first year of growth) would provide an independent estimate of age. Because the specimen used for the study was near maximum size, we assert that the findings of this study provide a minimum estimate of the longevity of giant sea bass.

Methods

Specimens and size

In January 2010, a near maximum size giant sea bass (500 pound or 227 kg was captured off Santa Cruz Island by commercial gill-netters legally targeting white seabass (*Atractoscion nobilis*). The giant sea bass was landed legally at Santa Barbara as incidental bycatch (one allowed per trip). Brian Colgate, the owner and manager of the Santa Barbara Fish Market, notified the senior author (with assistance from commercial fisherman Gary Burke) of the landing and made both the head and landing photograph of this large specimen available for scientific study. The head (57 cm in length) was transported to the Nearshore Marine Fish Research Program (NMFRP) laboratory at California State University Northridge for further study. In the laboratory, various morphometric measurements of the head including head length (HL) were recorded and both sagittal otoliths were extracted for use in ageing (left sagitta) and bomb radiocarbon analysis (right sagitta). Total length (TL) of the large specimen was estimated using the proportion of HL to TL based on a lateral view photograph of the specimen (Figure 2). The dressed weight (420 pounds or 191 kg minus viscera and gills) at landing was converted to round (undressed, whole) weight of 496 lbs (rounded to 500 lbs) using the equation, round weight = (1.15·dressed weight) − 0.46, calculated for large Atlantic wreckfish (*Polyprion americanus*) (Sedberry et 23 al. 1994).

A single small (145 mm TL) giant sea bass was collected on June 10, 2008, off Seal Beach, California, during a white seabass gill net survey conducted for the Ocean Resource and Hatchery Program (OREHP) of the California Department of Fish and Game (Allen et al. 2007). This specimen, known to be 1-year-old based on length change observations previously noted, was used to compare growth ring structure in the otolith

Fig. 2. A near maximum size (7 ft; 500 pound) giant sea bass (*Stereolepis gigas*) captured by an anonymous commercial fisherman (pictured) in January 2010 off Santa Cruz Island and legally landed at the wharf in Santa Barbara (photo courtesy of Jeffrey Cecilia, Santa Barbara Fish Market).

sections and to provide a reference for first-year growth within the core of the sagitta from the massive specimen (identify location of the first annulus).

Age estimation

Sagittal otoliths were removed using the method of Craig et al. (1999). In order to access the otoliths, the gill arches and flesh covering the parasphenoid bones were first removed. A hacksaw was used to cut through the basioccipital and parasphenoid bones, stopping at the capsular otic bulla, the chamber containing the semicircular canals and otoliths. Extracted otoliths were cleaned with freshwater and stored dry.

The left sagitta of each specimen (n = 2) were mounted on a wood block with cyanoacrylate adhesive for transverse sectioning. A 0.5 mm section through the focus was taken using a Buehler-IsoMet® double bladed, low speed saw with diamond edged blades separated by a stainless steel shim (Allen et al. 1995). Sections were removed from the blocks and polished using silicon carbide lapping paper on a lapidary wheel. Each section was placed in a black-bottomed watch glass filled with water and digitally imaged at 50× magnification under a Wild dissecting scope. Three separate images for the large specimen were merged into one composite image using Calico Panorama software (www.kekus.com). Annuli were counted directly from the digital images of these sections. Each section was read twice by both authors after initial full otolith section examinations and a collaboration on the interpretation of the innermost growth, based on early growth observations (i.e. Walford 1937; Fitch and Lavenberg 1971) and extrapolation of early growth rates (Shane et al. 1996).

Radiocarbon analysis

The whole otolith of the massive specimen was mounted on a glass slide with the sulcus side down, making the distal surface accessible for core extraction by micromilling. Cytoseal® was used as an adhesive and was allowed to cure for several days prior to further preparation. Because the adult otolith accreted a significant amount of otolith material onto the distal side of the otolith, hand grinding with 320- to 1000-grit wet-dry sandpaper (silicon-carbide) in water was necessary to expose the earliest otolith growth. The first few years of growth were clearly visible as grinding proceeded and the concentric growth zone structure was used as a guide in exposing the core. Milling was an extraction of the smallest core structure visible, which was defined as a small, crenulated otolith-core outline. This part of the otolith was more opaque than the more recently formed otolith growth layers and was used as a template for extraction with the micromilling bit.

Core material was extracted from the otolith using the computer automated capabilities of a New Wave Research® (ESI–NWR Division; Fremont CA 94538 USA) micromilling machine. A 0.5 mm diameter Brassler® (Savannah, GA 31419 USA) bit was used to drill an overlapping surface extraction within the oval dimensions of 6.0 mm long by 3.5 mm wide. The computer was used to guide the surface extraction over the uneven surface structure of the otolith (uneven from hand grinding and mount angle). A depth of 350 μm was extracted with two passes of the scan at 175 μm each. These dimensions were within the 1-year-old otolith dimensions of the smaller fish discussed previously and available material was sufficient to extract two separate samples from the otolith core. Both samples were submitted to the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) at the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts, for routine radiocarbon analyses.

Radiocarbon measurements were reported from NOSAMS as the Fraction Modern (Fm), which was used to calculate $\Delta^{14}C$ with a correction for natural isotopic fractionation. Fraction Modern is the measured deviation of the $^{14}C/^{12}C$ ratio from a "modern" sample, which is corrected for fractionation using a within-instrument $\delta^{13}C$ value for each sample. The calculated $\Delta^{14}C$ values reported in this study were also corrected for estimated age based on growth zone counts for an approximate time of formation and a calculated birth year (Stuiver and Polach 1977).

Regional $\Delta^{14}C$ reference chronology

Regional reference records from the northeastern Pacific Ocean were gathered to provide an age calibration source for the measured $\Delta^{14}C$ values from the otolith core of the massive specimen. Records of $\Delta^{14}C$ for the critical period, from pre-bomb to the rise in $\Delta^{14}C$ (after 1958–1959), were selected based on previous use in other studies and some regional similarities in timing and magnitude. Potential discrepancies and pitfalls were considered and described relative to the measured otolith $\Delta^{14}C$ values and conclusions of age. Pre-bomb $\Delta^{14}C$ values provided by the reference $\Delta^{14}C$ records were used to derive a mean $\Delta^{14}C$ value and a 2 SD upper limit for the pre-bomb period (Kerr et al. 2004). This upper limit was used to define pre-bomb *versus* post-bomb $\Delta^{14}C$ values measured in the core material from the massive specimen.

Bomb radiocarbon dating

Age was estimated based on the otolith $\Delta^{14}C$ values relative to the time for regional $\Delta^{14}C$ reference values were in agreement. The correlation between the otolith $\Delta^{14}C$ value and the regional $\Delta^{14}C$ reference records were initially attributed to a general region of the reference curve (pre-bomb, bomb rise, peak, or post-bomb decline; Andrews et al. 2011). A birth year, calculated based on the estimated age by growth zone counts, provided a temporal comparison. For pre-bomb levels, a minimum birth year and age was estimated based on the last year the level was measured, plus a nominal uncertainty of a few years based on the variations in the rise of $\Delta^{14}C$ as estimated by the 95% CI from the yelloweye rockfish $\Delta^{14}C$ record.

Results

Specimens and size

The head length (HL) of our large specimen was 57 cm. Based on the photograph of this specimen (Figure 2), this HL equates to a total length of 2.2 m (7 ft). The dressed weight (420 pounds or 191 kg minus viscera and gills) at landing corresponds to an estimated round weight of approximately 496 pounds (± 12 pounds). We therefore round up to 500 pounds (227 kg) for reporting purposes. From these data, we conclude that this specimen was approaching maximum known size for this species.

Age estimation

The right sagitta of the large specimen was extracted unbroken and measured 36.1 mm in length by 11.7 mm in width (max) and weighed 2.26 g (Figure 3). The rostrum of the left sagitta of the large individual was broken during extraction and is not pictured. The section from the single left sagitta of the small specimen (145 mm TL) was estimated to be 1-year-old based on length frequency observations previously discussed, which was supported by the presence of a single, well developed growth ring at the margin of the sectioned otolith (Figure 4). Using the width of this otolith as a reference starting point, the section of the massive specimen's sagitta yielded consistent counts of 62 rings along two axes of the ventral sulcus region (Figure 5). Based on growth zone counts age was estimated as 62 years old at capture, with a birth year of 1948.

Radiocarbon analysis

Two samples were successfully extracted from the otolith core of the massive *S. gigas* specimen (Table 1). The mass of these samples was low, but measureable by AMS; radiocarbon measurements are reported as Fraction modern (Fm), with calculated $\Delta^{14}C$ values. Each of the $\Delta^{14}C$ values is consistent with each other within the margin of instrument error.

Regional $\Delta^{14}C$ reference chronology

The regional $\Delta^{14}C$ reference records selected from the northeastern Pacific Ocean are a combination of otolith, invertebrate, and dissolved inorganic carbon (DIC) sources from both local and distant locations (Figure 6). The more distant $\Delta^{14}C$ reference records are

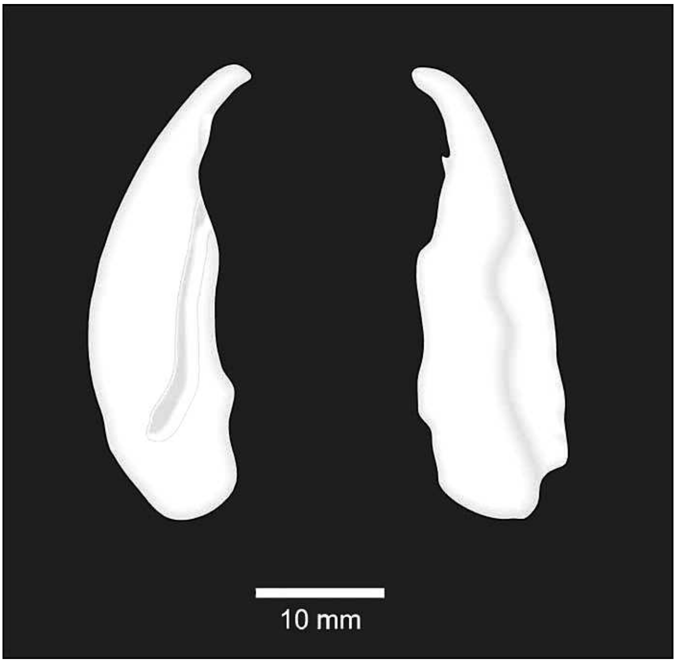

Fig. 3. Medial (left), and distal (right) view of the right sagitta from the 7 ft, 500 pound giant sea bass (*Stereolepis gigas*) captured in January 2010 off Santa Cruz Island, California. © Larry G. Allen.

from the Gulf of Alaska (GOA): 1) yelloweye rockfish (*Sebastes ruberrimus*; Kerr et al. 2004); and 2) Pacific halibut (*Hippoglossus stenolepis*; Piner and Wischniowski 2004). These records, despite their distance from the SCB, are necessary for the comparison because they are the nearest comprehensive $\Delta^{14}C$ records that provide an indication of when the rise in $\Delta^{14}C$ occurred for the northeastern Pacific Ocean. Each provides measured $\Delta^{14}C$ values from the pre-bomb to post-bomb and a basis for the approximation of a rise time for $\Delta^{14}C$ in the SBC. Reference $\Delta^{14}C$ records and values from the SCB are from known-collection-year white abalone shells (*Haliotis sorenseni*; A.H. Andrews, unpublished data) and estimated-age cowcod rockfish (*Sebastes levis*; Andrews, unpublished data). Known age and estimated age material from all of these sources were used to provide a baseline mean value for pre-bomb $\Delta^{14}C$ levels, as well as a few post-bomb $\Delta^{14}C$ references, in the SCB. Measurements of $\Delta^{14}C$ from samples with estimated age were chosen as a reference because once pre-bomb $\Delta^{14}C$ levels are reached the time-specificity of the measurement is restricted to a minimum age value is irrelevant. The pre-bomb reference for $\Delta^{14}C$ levels for white abalone and cowcod were previously established based on the increase in $\Delta^{14}C$ from other measurements (A.H. Andrews, unpublished data). Mean pre-bomb $\Delta^{14}C$ within the SCB was −85.0‰ (± 6.9 SD) with an upper limit (2 SD) of −71.2‰ as the criterion for measured $\Delta^{14}C$ levels that would be considered post-bomb when exceeded. Specific to this study, we used this value to define pre-bomb *versus* post-bomb $\Delta^{14}C$ values measured in the giant sea bass otolith core material.

In support of the 2 SD criterion for pre-bomb designation, $\Delta^{14}C$ values measured in DIC from various locations were gathered to document the regional rise of $\Delta^{14}C$ and the variability of post-bomb levels. A record from Scripps Pier provided a first rise of $\Delta^{14}C$

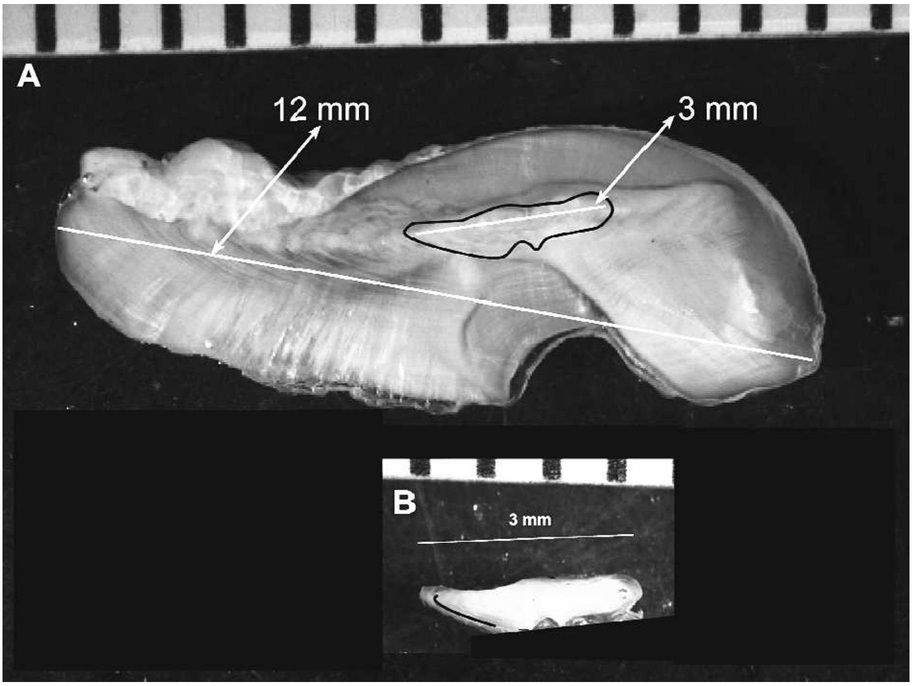

Fig. 4. Thin, transverse cross-section of the left sagitta from the massive specimen of giant sea bass (A), with a transverse section of the left sagitta from a 145 mm TL, 1-year-old (B) giant sea bass (first year growth ring indicated by black line). The dorso-ventral height of the otolith in cross-section from the massive fish was 12 mm and the 1-year-old was 3 mm. The outline of 'B' section was superimposed on to 'A' section to delineate where the first ring was identified for age estimation of the large specimen. All rings proximal to the core were considered as sub-annual structures within the first year of growth.

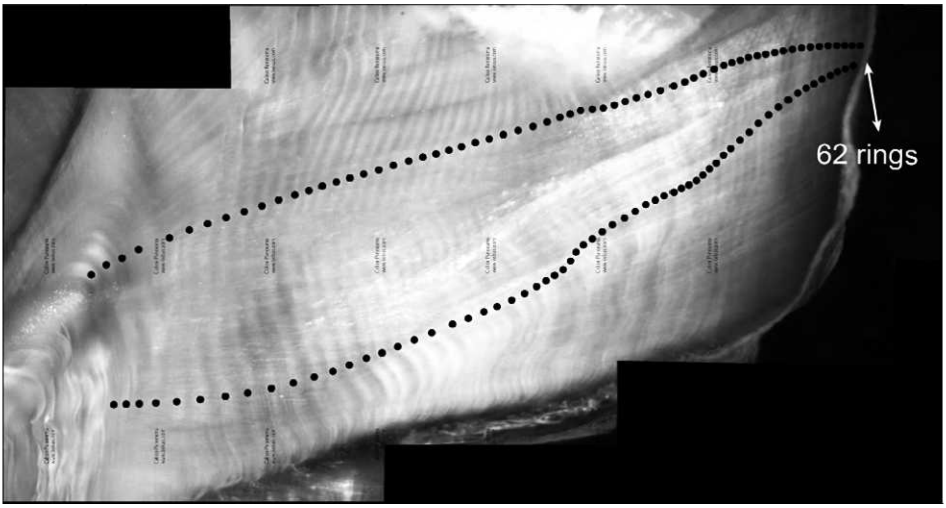

Fig. 5. Transverse otolith (left sagitta) section (0.5 mm thick), observed with reflected light (50×), from the massive giant sea bass captured in January 2010 off Santa Barbara, CA. Counts of 62 opaque annual bands (black dots) along two axes of the ventral sulcus region.

Table 1. Sample data for extractions made from the otolith core of the massive *S. gigas* specimen. Because the measured $\Delta^{14}C$ values were classified as pre-bomb, only a minimum age can be determined from the last year these values were recorded in the reference series (Figure 6). Minimum birth year and age from were based on the rise time common among $\Delta^{14}C$ references (~1958–59). Samples were processed in 2011 and corrected to the estimated date of formation (1948). Correction for fractionation with measured $\delta^{13}C$ was made on-line (during sample processing) by the AMS and is not recorded in the output.

Sample number	NOSAMS number	Sample weight (mg)	Fraction modern	$\Delta^{14}C$ (‰)	$\Delta^{14}C$ birth year & age	Growth zone birth year & age
GSB 2010A	OS-86916	0.9	0.9214 ± 0.0036	−78.4 ± 3.6	Pre-1959 (>51 yr)	1948 (62 yr)
GSB 2010B	OS-86917	1.7	0.9229 ± 0.0036	−76.9 ± 3.6	Pre-1959 (>51 yr)	1948 (62 yr)

for August 1959 (mean = −53‰), with two post-bomb values increasing in concert with the $\Delta^{14}C$ slope from GOA to a maximum of 138‰ in 1969 (Linick 1978). Post-peak $\Delta^{14}C$ values for DIC revealed a moderate decline for winter conditions (outside the period of upwelling) from two data points, one in October 1980 (109‰) and the other in 1987 (92‰; Druffel and Williams 1991, Williams et al. 1991). A seasonally comprehensive $\Delta^{14}C$ record, covering the period of upwelling, indicated that changes in $\Delta^{14}C$ within a year could be on the order of 100‰ in the post-bomb period (Robinson 1981). This level of seasonal signal attenuation is similar to the findings for white abalone shell material with known collection year (unknown collection month; A.H. Andrews, unpublished data). In general, the post-bomb $\Delta^{14}C$ records provide support for minimum levels in the SCB over time and confidence in pre-bomb classification for $\Delta^{14}C$ values below the 2 SD criterion.

Bomb radiocarbon dating

Estimated age was based on the measured $\Delta^{14}C$ values relative to the time where regional $\Delta^{14}C$ reference values were in agreement, leading to a pre-bomb period classification (Figure 6). The two $\Delta^{14}C$ values are consistent with the reference $\Delta^{14}C$ values from the SCB and below the 2 SD criterion (Table 1). Because the measured $\Delta^{14}C$ values were classified as pre-bomb, only a minimum age can be determined from the latest year these values were recorded in the reference series. Birth year and estimated minimum age was objectively based on the agreement of the measured $\Delta^{14}C$ values with the loess curve of the yelloweye rockfish $\Delta^{14}C$ record (similar to the Pacific halibut $\Delta^{14}C$ rise time and the 1959 $\Delta^{14}C$ value from Scripps Pier). Minimum birth year from this congruence would be 1959 for a minimum age of 51 years. A more conservative estimate of 49 years from the 95% CI (1961 = latest birth year for the measured $\Delta^{14}C$ values) is also possible, but given the uncertainty in the yelloweye rockfish $\Delta^{14}C$ record, it is unlikely.

The birth year calculated from the growth-zone derived age is consistent with the pre-bomb classification of the otolith core material. The 62-year growth-zone age estimate is supported by the minimum $\Delta^{14}C$ age of 51 years. These findings also provide a level of confidence in the growth zone interpretations from the otolith thin-section.

Discussion

The estimate of 62 years for the massive specimen reported here is similar to what may be the most reliable, prior age estimates. For giant sea bass approaching maximum size,

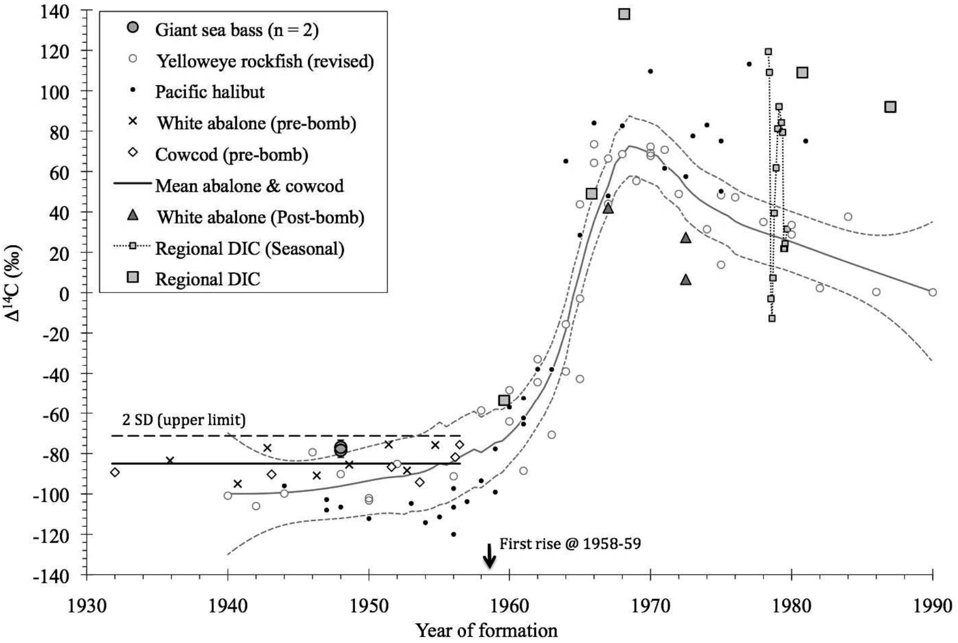

Fig. 6. Plot of two measured giant sea bass Δ^{14}C values from an otolith core estimated as 62 years old (birth year 1948), relative to changes in radiocarbon (Δ^{14}C) from atmospheric testing of nuclear bombs over time as recorded by various Δ^{14}C reference records. Yelloweye rockfish (Kerr et al. 2004) and Pacific halibut (Piner and Wischniowski 2004) otoliths provide the nearest comprehensive reference chronology from the GOA. Pre-bomb Δ^{14}C values from white abalone shell and cowcod rockfish otoliths in the SCB provide a regional Δ^{14}C context. The revised yelloweye Δ^{14}C record (A.H. Andrews, unpublished data) and the Pacific Halibut record provide a time-specific reference for the common rise in Δ^{14}C in the northern Pacific Ocean (~1958–59). Mean Δ^{14}C from white abalone and cowcod rockfish, with a calculated 2 SD upper limit, provide a basis for classifying the measured Δ^{14}C values as pre-bomb (earlier than ~1958–59) using otolith core material of the massive giant sea bass specimen. A loess curve fitted to the yelloweye rockfish Δ^{14}C data (with 95% CI) provides a centralized graphical distribution for these data. Other Δ^{14}C reference records from DIC measurements within the SCB and off central California provide regional references for the post-bomb behavior of Δ^{14}C (Linick 1978, Druffel and Williams 1991, Williams et al. 1991).

reported age estimates on the order of 60 to 70 years were similar to our findings. Bomb radiocarbon dating produced a minimum estimate of approximately 51 years for this specimen, thus providing support for the age derived using growth zone counts. The early estimates of age were derived using outdated techniques on whole otoliths and it is uncertain how these numerical estimates were quantified. The otolith thin-sections used in this study provided regular growth increments that were easily quantifiable and similar in pattern to those of other polyprionid species with similar longevity estimates.

The combination of Δ^{14}C reference records provides evidence for a common Δ^{14}C rise time from bomb-produced radiocarbon. Despite the minor difference in mean pre-bomb Δ^{14}C levels between the GOA and the SCB, the rise times among Δ^{14}C records from the northeastern Pacific were similar and converge in 1958 to 1959. It is currently unknown what the specific rise time is for the SCB, but it is reasonable to assume that the timing is similar for the northeastern Pacific because of global similarities in the Δ^{14}C rise time (Druffel 2002). In addition, the data series from Scripps Pier provide evidence for a simultaneous Δ^{14}C rise at approximately 1959, similar to the yelloweye rockfish and

Pacific halibut records. Improved $\Delta^{14}C$ records within the SCB would provide greater confidence in estimating age from this approach, but it is unlikely that the minimum longevity estimate would change by more than a few years due to regional upwelling.

Several species of wreckfish (Polyprionidae) have been studied for age and growth. A single congener, *Stereolepis doederleini*, is a large demersal species of the northwestern Pacific whose life history is little known, but two species of the other genus (*Polyprion*) in this family, support important international fisheries and have been aged. Based on growth zone counts of otolith thin-sections, the maximum age for Atlantic wreckfish (*Polyprion americanus*) exceeds 70 years, with validation for the earliest growth from daily increments and margin type analyses (Peres and Haimovici 2004). For the New Zealand hapuku (*Polyprion oxygeneios*), age estimates from otolith thin-sections, supported by tag-recapture evidence of early growth, indicate a longevity exceeding 60 years (Francis et al. 1999). While members of the genus *Polyprion* are not ecologically similar to *S. gigas*, the age estimates from growth zone counts of otolith thin-sections provides evidence that such longevity is reasonable. Reports of a 100-year longevity in the literature and on the Internet, however, were a promulgation of an off-the-cuff estimate made in Fitch and Lavenberg (1971) that remains unfounded.

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