Bulletin of the Southern California Academy of Sciences

Volume 104 | Issue 1

Article 2

2005

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Bull. Southern California Acad. Sci.
104(1), 2005, pp. 14–25

Age and Growth of Spotted Sand Bass, *Paralabrax maculatofasciatus,* in Bahia de Los Angeles, Baja California, Mexico, with Age Validation using Otolith Edge Analysis

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Abstract.—Spotted sand bass, *Paralabrax maculatofasciatus,* were collected from Bahia de Los Angeles, Baja California, Mexico covering as wide a size range as possible over four seasons (spring, summer, fall, and winter). Age was estimated and growth parameters calculated from growth zones counted in transverse otolith sections. An otolith edge analysis indicated an opaque growth zone was deposited once per year during the summer, validating the annual periodicity. Spotted sand bass from this region are fast growing with a relatively short life span of up to 11 years. Growth differs from the disjunct Pacific coast population by having a higher growth rate and a shorter longevity.

Introduction

Spotted sand bass, *Paralabrax maculatofasciatus,* are a common nearshore fish ranging from Mazatlan, Mexico, into the Gulf of California, and north to Monterey Bay, California (Miller and Lea 1972). One collection in the late 1800's placed this species as far north as San Francisco, California, but it is more common in warmer waters and is rarely encountered north of Newport Bay in southern California (Love 1996). The ecology and life history of spotted sand bass off southern California and the northern Baja California coast is well documented (Butler et al. 1982; Oda et al. 1993; Allen 1985; Allen et al. 1995; Hovey and Allen 2000; Bocanegra-Castillo et al. 2002) and less is known for the disjunct population of the northern Gulf of California (Hastings 1989; Ferry et al. 1997). Age and growth characteristics of spotted sand bass have been described and validated for the southern California population (Allen et al. 1995), but have not been described for the Gulf of California population.

There are two disjunct populations of spotted sand bass in the eastern Pacific Ocean; 1) those found along the Pacific coast of California and northern Baja California, and 2) those in the northern Gulf of California. On a geological time scale these populations were probably joined into a single larger population before being separated by the Baja Peninsula due to oceanographic and geologic processes (Case et al. 2002). Warm water temperatures at the tip of the Baja California Peninsula seem to preclude movement of spotted sand bass between the two populations, as is evidenced by the genetic divergence of the two populations

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(Tranah and Allen 1999; Stepien et al. 2001); hence, growth characteristics may be different from the Pacific coast populations.

The objectives of this study were to: 1) estimate the age and growth characteristics of spotted sand bass from Bahia de Los Angeles in the northern Gulf of California by counting growth zones in transverse otolith sections, 2) validate the annual periodicity of growth zone formation by performing a seasonal edge analysis, and 3) compare growth characteristics of the Gulf of California population with the characteristics described for the southern California spotted sand bass (Allen et al. 1995).

Materials and Methods

Spotted sand bass were collected in and around Bahia de Los Angeles, Baja California, Mexico (Figure 1). Collection methods consisted of hook-and-line, Hawaiian sling pole spears, and beach seining. Fish were collected mid-season, approximately 3 months apart, over several years (1992, 1994, and 1995). Sampling events were designated as seasonal by collection dates and categorized as spring, summer, fall, or winter (Table 1). Sampling efforts were focused within each season to collect fish covering as much of the full size range as possible and under-represented length classes were targeted as sizes became well represented; a sample size of approximately 20 fish per 10 mm length class was considered adequate. We targeted different length classes by selecting size appropriate gear (e.g hook size, pole spears, beach seine) and sampling location and depth. The parameters of weight (g) and standard length (SL, mm) were recorded for each fish collected. Both sagittal otoliths were extracted, cleaned, labeled, and stored dry. Sex determination was not attempted because the northern Gulf of California population of spotted sand bass is known to exhibit protogynous hermaphroditism (Hastings 1989; Hovey and Allen 2000).

Fish ages were estimated from transverse sagittal otolith sections mounted on microscope slides and viewed under a dissecting microscope with transmitted light. Transverse sections containing the nucleus were removed using a Buehler® Isomet low-speed bone saw with two Norton® low-density diamond blades separated by acetate spacers (0.6 mm). Sections were placed on a slide and mounted with Cytoseal™ epoxy. Sections were thinned and polished to optimal viewing thickness using a Buehler® Ecomet III lapping wheel with 600 grit silicon carbide, wet/dry sandpaper.

Ageing criteria were based on well-defined growth zones (Figure 2). The sulcal region exhibited the clearest growth zones for ageing and was the region used to count annuli. Otolith sections with growth zones that could not be counted were disregarded. Young-of-the-year (YOY) fish that had not formed the first opaque zone were aged as zero years because they had not completed the first year's growth. Thereafter, the formation of each opaque growth zone was interpreted to represent a single year's growth.

Edge analysis was performed on the transverse sections of all aged otolith sections. Edge types were defined as translucent or opaque to transmitted light. The otolith section was not considered for edge analysis if the edge type could not be resolved. Validity of the annual age estimates was based on whether there was a seasonal formation of the opaque growth zone. Three readers independently aged readable otoliths three times each. Otolith readers consulted with each other

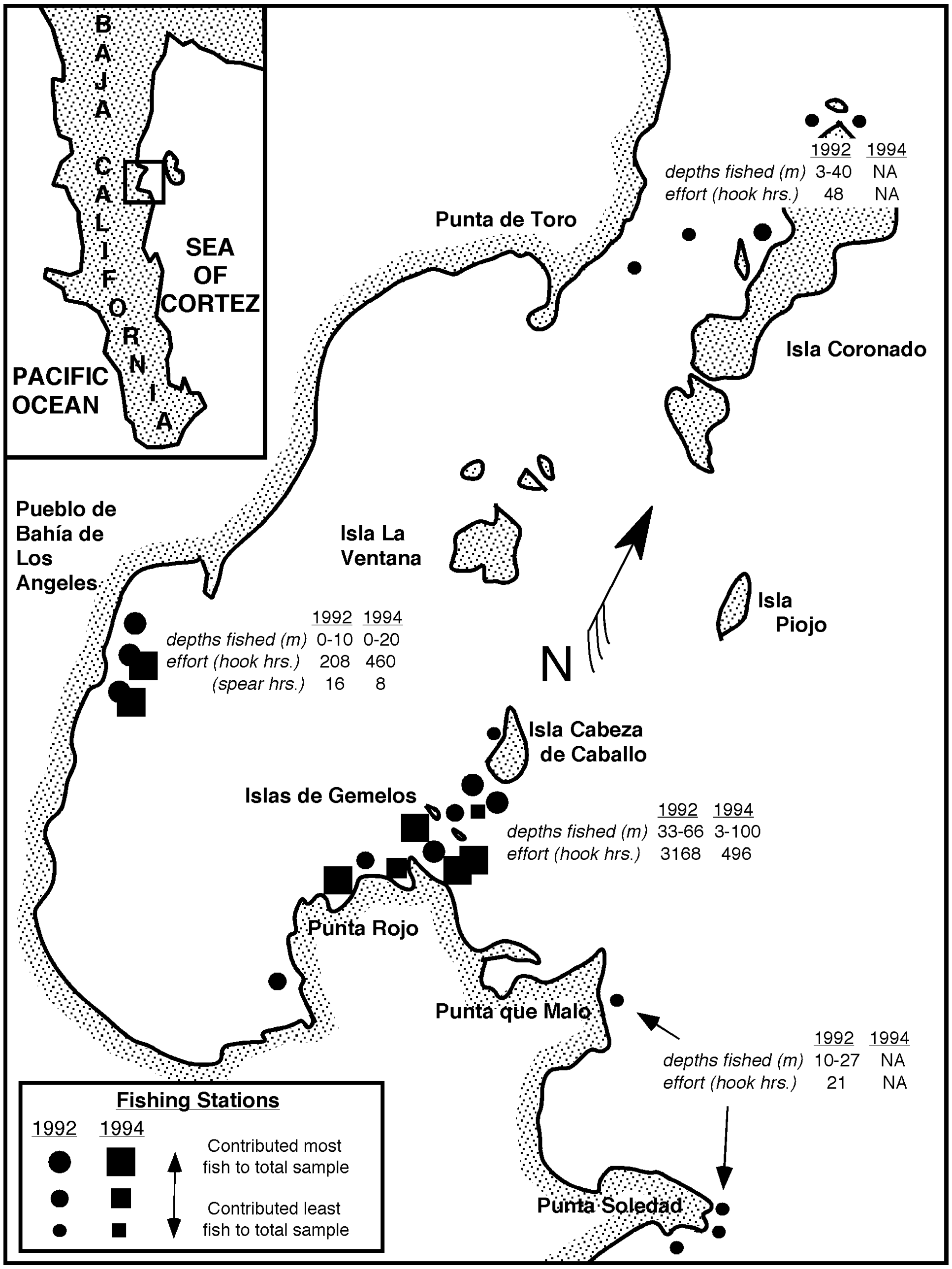

Fig. 1. Map of the Bahia de Los Angeles region with sites sampled and sampling effort. Samples taken in 1995 were from a fisherman at the beach in Bahia de Los Angeles (summer) and from locations intermingled with the sites near town and Punta Rojo (winter).

Table 1. Definition of season category based on collection dates.

Season	Dates of collection
Spring	27 March to 2 April 1994
Summer	12 to 21 July 1994, and 1 to 15 July 1995
Fall	15 to 23 October 1992
Winter	9 to 20 January 1995

to set criteria for counts and to resolve differences. Otoliths that did not meet agreed upon criteria were disregarded. Average percent error (APE) and index of precision (D) were calculated to assess variability of age estimation within and between readers (Chang 1982; Campana 2001). A von Bertalanffy growth function was calculated from estimates of age and fish length using FISHPARM software. An allometry growth function was also estimated for the relationship of fish weight and length to describe somatic growth. An estimate of longevity was calculated using the exponential nature of the von Bertalanffy equation, where 95% longevity (yr) = 5 ln(2)/k (H. Mollet, Pacific Shark Research Center, Moss Landing Marine Laboratories, personal communication), and k represents the growth coefficient.

The growth rate estimated from our study was compared to the growth from data analyzed by Allen et al. (1995). This latter study assumed an age of six months (0.5 yr) for YOY, differing from our assumption of age zero for YOY. To compare growth between the two studies, Allen et al. (1995) provided their data and we adjusted it to match our criteria. Length at age data was log-transformed for both data sets. Calculated growth rates (slopes) were compared between the Pacific coast and Gulf of California populations using an analysis of covariance (ANCOVA). In particular, the ANCOVA will determine if the slopes of these lines are parallel (i.e. if fish in these populations grow at the same rate). Prior to testing for differences between the Gulf and Pacific coast populations,

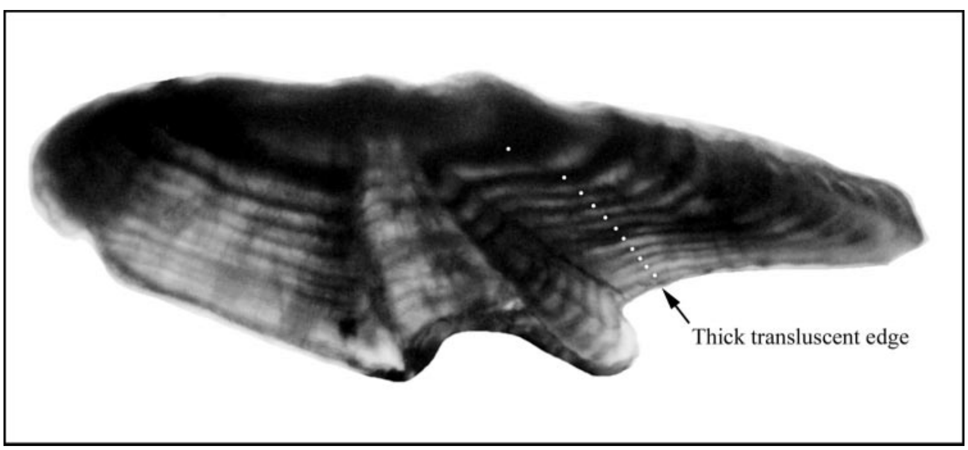

Fig. 2. Image of the transverse otolith section from the oldest aged fish. Age from growth zone counts was 11 years and is denoted with a small white spot on each counted annulus. Note that this fish was collected in the Spring and that the section has a thick translucent edge (the dark edge is an edge-effect artifact of the transmitted light).

Table 2. Collection season and year with length and weight ranges and the number of fish collected for each sampling period.

Season	Length range (mm SL)	Weight range (g)	Sample size (*n*)
Spring (1994)	32–322	5–750	169
Summer (1994)	85–320	15–860	76
Summer (1995)	125–264	n/a	18
Fall (1992)	56–307	14–709	269
Winter (1995)	69–300	5–760	72

ancillary data for three small fish collections made north of Bahia de Los Angeles (Los Pulpos, Puertocitos, and Gonzaga Bay) were analyzed in the same manner to investigate potential growth differences in other parts of the northern Gulf (Larry Allen, CSU Northridge, unpublished data).

Results

Six hundred and four spotted sand bass were collected from various nearshore and island locations in Bahia de Los Angeles, Baja California, Mexico. Most were captured using hook-and-line over bottom depths of 6–45 m. The smallest specimens were collected in spring 1994 with a beach seine in shallow water over a sandy bottom. Specimens collected using pole spears were gathered in 1–10 m of water at the rock-sand interface.

During each season, the collection effort, length and weight ranges, and the number of fish caught differed (Table 2). The majority of the specimens (approximately 45%) were collected in fall 1992. The smallest (32 mm SL, 14 g) and the largest (322 mm SL, 750 g) fish were collected in spring 1994. The narrowest fish length range (125–264 mm SL) and fewest fish (N = 18) were collected in summer 1994. Size and age frequency histograms were not constructed because of the size-targeted nature of the sampling effort, resulting in the release of many fish with lengths for which sampling was sufficient. Furthermore, gear selection bias could not be corrected (e.g., selecting hook size to target smaller or larger fish, net mesh on beach seine, difficulty targeting small fish with pole spears, etc.).

An allometric equation adequately described the length-weight relationship for 554 of the spotted sand bass collected ($R^2 = 0.956$, Figure 3). The heaviest fish collected (860 g) was also one of the longest (320 mm SL). The six fish that weighed greater that 700 g were not the oldest and ranged from 3–7 yr. The oldest fish (11 yr) weighed 525 g and was 308 mm SL.

Two otolith readers aged 556 spotted sand bass from the Gulf of California, of which 508 were deemed readable by both readers, and estimated age ranged from 0 yr for YOY to 11 yr (Table 3). Otoliths were easy to read and age estimates were very repeatable, as was evidenced by the 93% agreement between readers. Few readings deviated by more than 1 year and age differences were never more than 2 years. Reader disagreement was very low as was indicated by an APE and D of 1.4%, and a CV of 2.0%. Young-of-the-year fish were collected in all seasons except summer. The widest range of age estimates came from the spring 1994

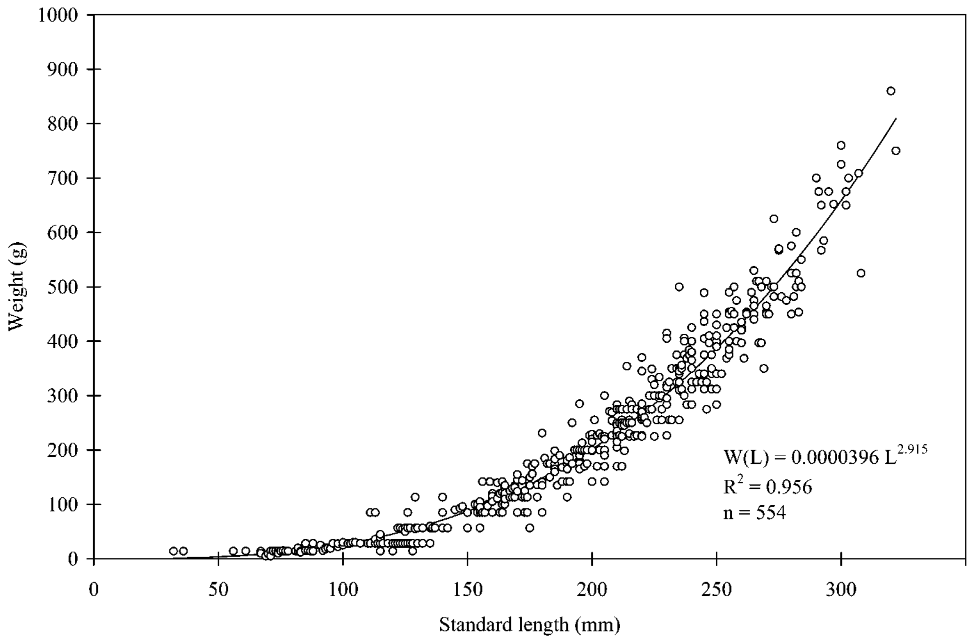

Fig. 3. Plot of a logistic growth function fitted to the weight and length of the fish collected.

samples. A minimum of about 60% of the age range observed was collected during any season.

A von Bertalanffy growth function (VBGF) was fitted to the age estimates (Figure 4). The fit was good (R^2 = 0.827) and the VBGF indicated the growth rate was relatively high (k = 0.296 ± 7.3%) with a predicted maximum size (L_∞) of 300 ± 2.5% mm SL. Based on the exponential nature of the von Bertalanffy function, 95% longevity is about 12 yr.

Readers identified edge types as either translucent or opaque. Agreement between readers for edge type was 90%. Disagreement was highest for summer and fall (16%) and 2 to 3% for spring and winter. For sections where disagreement on edge type was irresolvable, the section was removed from consideration, resulting in a total of 499 otolith sections used in the edge analysis. Irresolvable edge type was typically for sections that were not the best quality and with older aged fish; determining edge type for older sections was usually the most difficult because the growth zones were more compressed. The greatest incidence of oto-

Table 3. Age ranges and number of spotted sand bass aged from each sampling season in the Gulf of California.

Season	Age estimates (yr)	Sample size (n)
Spring (1994)	0–11	164
Summer (1994)	1–7	73
Summer (1995)	1–7	15
Fall (1992)	0–10	236
Winter (1995)	0–6	68

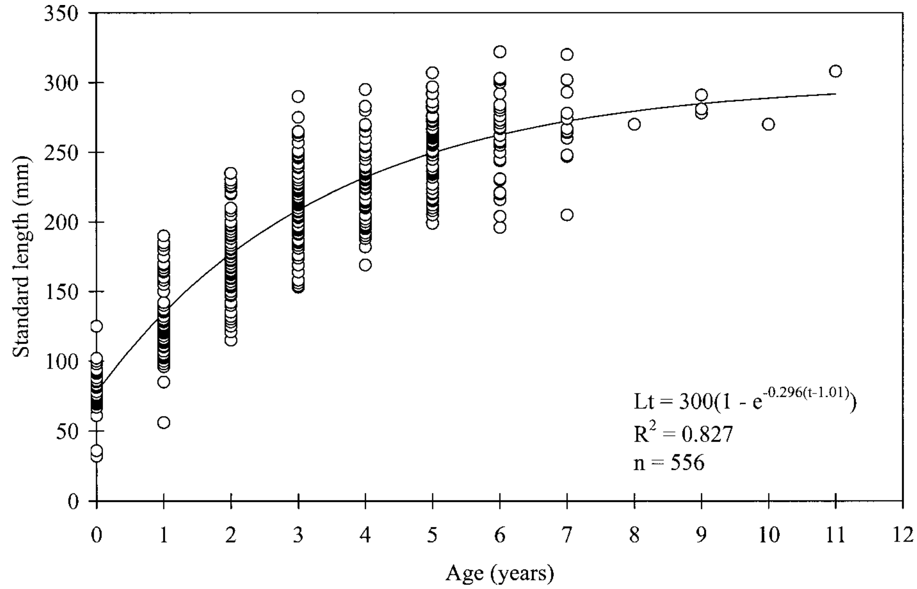

Fig. 4. Plot of the von Bertalanffy growth function fitted to the length and age data for spotted sand bass. Note the considerable variation in size with age and that some fish grow very quickly, some approaching 200 mm SL bay and age of 1 yr.

liths with opaque edges occurred in samples collected during summer periods (83%; Figure 5). Edges of spotted sand bass otoliths from the other three seasons were mostly translucent (84–95%).

The ANCOVA indicated that growth rates within the northern Gulf were not significantly different ($p = 0.340$), but did differ for the Pacific coast population ($p<0.001$, Figure 6). Hence, spotted sand bass grow faster in the Gulf of California than they do in Pacific coast waters. Log-linearized growth rates can be translated into a rate of mm/year. Fish in the Gulf population are growing at an average rate of ca. 27 mm/year, whereas the Pacific coast population are growing at an average rate of ca. 10 mm/year; less than half that of the Gulf population.

Discussion

Spotted sand bass are one of the most common nearshore fishes in Bahia de Los Angeles and were readily caught in every season except winter. During winter sampling they were uncommon and skittish at free diving depths (<10 m), and were either not biting or not present at fishing sites where they were abundant in the other three seasons. Fishing at greater depths (30–45 m) led to more frequent encounters with gold spotted rock bass (*P. auroguttatus*) in all seasons (Pondella et al. 2001). One marked exception was an aggregation of large spotted sand bass over sand at the mouth of a small cove near deep water (>50 m) at the southern entrance to Bahia de Los Angeles. These large adults (210–295 mm SL) readily took bare hooks and seemed to be exhibiting an aggregational behavior similar to that observed in Southern California waters (Larry Allen, CSU Northridge, personal communication).

Spotted sand bass from Bahia de Los Angeles did not differ in growth from

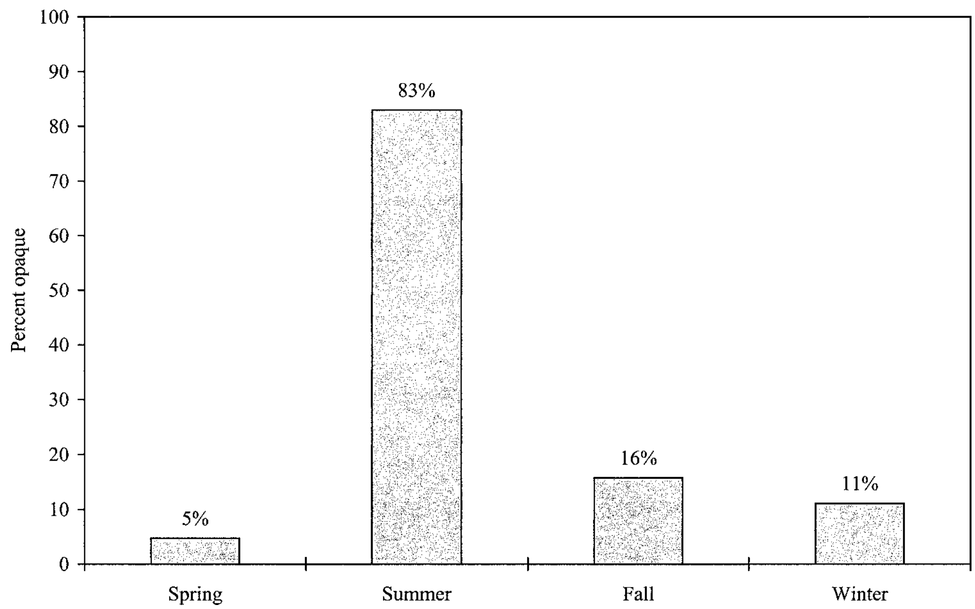

Fig. 5. Frequency histogram of edge type determined from transverse otolith cross sections. A total of 499 otoliths were used in the edge analysis (Spring n = 161, Summer n = 74, Fall n = 198, Winter n = 66). The percentage of opaque edge type is given on top of the bars for each respective season.

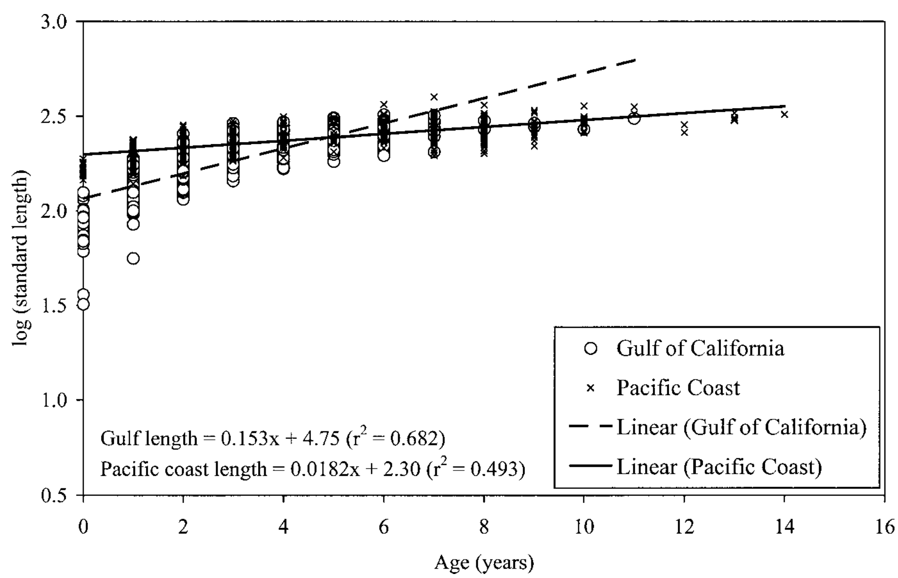

Fig. 6. Plot of log-linearized standard length and age for the Pacific coast population (Allen et al. 1995) and the Bahia de Los Angeles population with the corresponding regressions used to calculate growth trajectories.

fish collected further north in the Gulf, but this finding must be qualified by the low samples size and limited size range of these collections. To further check for differences we added the aged fish to the VBGF data from Bahia de Los Angeles to see if it changed the parameters to any extent that could be considered significant. The criteria used was the 95% confidence interval for the VBGF parameters. The growth coefficient (*k*) decreased slightly to 0.256 ± 7.7% and the asymptotic length (L_∞) increased slightly to 314 ± 2.9% mm SL. Neither changed significantly in this rather subjective test and we concluded that growth in the northern Gulf is probably similar throughout the region.

The growth trajectory of spotted sand bass in Bahia de Los Angeles differs from that of the Pacific coast populations as well as its congeners. Specifically, spotted sand bass in the northern Gulf grow faster than those found in Pacific coast populations, contrasting greatly in terms of the growth coefficient (>0.25 vs 0.1077; Allen et al. 1995). This is also much higher than that of its longer-lived congeners, kelp bass (*P. clathratus, k* = 0.06; Love et al. 1996), barred sand bass (*P. nebulifer, k* = 0.08; Love et al. 1996), and golden spotted rock bass (*P. auroguttatus, k* = 0.115; Pondella et al. 2001). In addition, this growth rate is more typical of tropical serranids and resides among the faster growing fishes (e.g. Manooch 1987). In this study, some one year old fish had reached nearly 200 mm SL and some had exceeded this length by their second year. The relatively high growth rate described in this study is driven by the small fish collected from Bahia de Los Angeles coupled with growth to large size within the first few years, and its relatively short longevity (11–12 yr).

It is possible that larger, and presumably older, fish were missed in Bahia de Los Angeles despite our collection efforts. A maximum length of 559 mm total length (TL; ca. 500 mm SL) is given for spotted sand bass (Thomson et al. 1979). This is much larger, however, than any specimen reported here or by Allen et al. (1995). A follow up communication about the source of the high maximum length revealed that there was no support for the claim (Lloyd Findley, CIAD-Unidad Guaymas, personal communication). As a result, the maximum length of spotted sand bass in the Gulf of California was reduced to a substantiated 381 mm TL (ca. 336 mm SL) in the revised edition of *Reef Fishes of the Sea of Cortez* (Thomson et al. 2000).

The length-weight relationship, when considered with respective ages, is useful in describing the variability of growth for this species. Spotted sand bass can become large fish in a relatively short period of time, while smaller fish can be considerably older than the largest fish. In this study, the oldest fish was a low weight individual with a length close to the longest fish (525 g at 308 mm SL). This fish seems atypical of the Bahia de Los Angeles population. The largest fish, those with the greatest weights and lengths, had low to average ages (3–7 yr). The largest individual in this study weighed only half as much as the largest spotted sand bass taken in the southern California population (>1800 g at 400 mm SL; Allen et al. 1995). While the differences in size and age between the Pacific population and the Gulf population can be explained by the disjunct distribution of the species (Trahan and Allen 1999), the plasticity of size and age within the population is a bit of a mystery. It may be explained by localized habitat variability, timing of oceanic events, or competition to broadly qualify a few factors. The oldest fish not being the largest or heaviest fish, however, is becoming a relatively common observation in fishes (e.g. rockfishes, Cailliet et al. 2001).

Despite the limited temporal resolution of a seasonal application of the edge analysis, the results indicate the annual interpretation of growth zones in otolith sections is valid for spotted sand bass in Bahia de Los Angeles. Sampling once per month over a period of one year would have been optimal (Campana 2001), but the remote nature of Bahia de Los Angeles precluded this kind of sampling design. Based on the seasonal sampling, it is clear that an opaque growth zone is formed once a year over the summer months with a low probability of the opaque zones forming in any other season. The other northern Gulf collections made at a time that corresponds with our Spring collections had a low incidence of opaque zone formation (13%); it is interesting to note that the Gonzaga Bay collections had the highest incidence of early opaque zone formation (24%, n = 46). In addition, the timing of opaque zone formation is in agreement with the findings for the Pacific coast populations (Allen et al. 1995).

Spotted sand bass in the Bahia de Los Angeles region are fast growing fish that can attain an age of about 11 yr, a length of about 320 mm SL, and a weight of at least 820 g. In Bahia de Los Angeles they grow faster than fish in the southern California population, but attain a smaller maximum size and a younger maximum age (Allen et al. 1995). The average annual water temperature of Bahia de Los Angeles is higher and has a much greater range than is recorded for the southern California environment (Tranah and Allen 1999). Specific to the Bahia de Los Angeles region, a strong seasonal upwelling is induced by high wind and current speeds in the Canal de Ballenas, just outside the bay, coupled with the rugged island bathymetry. As a result of the upwelling conditions, Bahia de Los Angeles is one of the most productive regions in the Gulf of California (Thomson et al. 2000, Case et al. 2002). It is likely that temperature differences, coupled with the high seasonal productivity, explain the observed growth trajectory differences between the two populations.

Acknowledgements

We would like to thank most sincerely Dr. Jose Mercadé and the Glendale Community College Baja Field Studies Program for providing a field station and in helping with organizing field collecting logistics. Thanks to Larry Allen, Tim Hovey and some of his students (CSU, Northridge) for the ancillary northern Gulf fish ageing data used in this study. Special thanks to Carolina Espinoza at the Museo de Bahia in Bahia de Los Angeles for help with regional information and field trip planning. Many thanks to Cheryl Baduini, Tanya Bennett, Erica Burton, Karen Crowe, Lara Ferry-Graham, Korie Johnson, Lisa Kerr, Debbie Nebinzahl, Linda Snook, Richard San Fillipo, and Jodi Thomas for helping with collecting and processing fish, and for making these research trips successful and so much fun. Special thanks to Shirley Andrews and Carolina Espinoza for feeding hungry researchers. Thanks to Mike Foster and John O'Sullivan for support through use of boats and other necessary field equipment. Thanks also to Erica Burton, Larry Allen, and an anonymous reviewer for assistance in improving the manuscript. Thanks to the Dr. Earl H. Myers and Ethel M. Myers Oceanographic and Marine Biology Trust and the Padi Foundation for financial grants to support the return trips to the region for seasonal sampling. Thanks to California State University, Fresno for use of a 4×4 truck and their understanding when it was returned in worse shape than when it left the parking lot. Finally, we express sincere appreciation to the late former Director of Moss Landing Marine Laboratories, Dr. John H. Martin, for providing the funding, equipment and supplies for the Advanced Topics in Ichthyology class project excursion to Bahia de Los Angeles in 1992; it was this trip that started the age and growth endeavor.

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Accepted for publication 16 September 2004.