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Otolith-based growth estimates and insights into population structure of White Seabass, *Atractoscion nobilis*, off the Pacific coast of North America

Alfonsina E. Romo-Curiel[a], Sharon Z. Herzka[a,*], Oscar Sosa-Nishizaki[a], Chugey A. Sepulveda[b], Scott A. Aalbers[b]

[a] *Departamento de Oceanografía Biológica, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), No. 3918 Carretera Tijuana-Ensenada, Ensenada, Baja California CP 22860, Mexico*

[b] *Pfleger Institute of Environmental Research (PIER), 2110 South Coast Highway Suite F, Oceanside, CA 92054, USA*

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ABSTRACT

White Seabass (*Atractoscion nobilis*; Sciaenidae) comprise an important commercial resource in the USA and Mexico, but there are few growth rate estimates and its population structure remains uncertain. Growth rates were estimated based on otolith analysis of fish collected at three locations spanning 1000-km. Variations in growth rates were assessed at the population level and by reconstructing individual growth trajectories. Seabass were sampled from fisheries operating off southern California (SC) and the northern and southern (NBC and SBC) Baja California peninsula from 2009 to 2012 ($n = 415$). Ages ranged from 0 to 28-years, but fish >21-years of age were sampled infrequently. Size-at-age was highly variable, particularly for fish <5-years. White Seabass grew quickly during the first 8-years of life after which growth rates decreased considerably. Fitting the size-at-age data with the von Bertalanffy growth function and applying the likelihood ratio test to parameter estimates indicated that SC, NBC and SBC did not differ significantly in growth rates (0.18–0.19-yr^{-1}) or asymptotic length (141-cm total length). Individual otolith growth trajectories showed high variability within regions and there were only significant differences in the average width of the first annuli. However, residual analysis of the average annual radii suggests fish from SBC had a larger size-at-age. Those differences may be related to the higher coastal temperatures found in southern coastal waters. Although growth rates may differ during the first year of life, findings suggest growth to be similar across the study range.

1. Introduction

The sciaenid *Atractoscion nobilis*, or White Seabass, is distributed along the Pacific coast of North America from northern California, USA, to southern Baja California, Mexico and within the Gulf of California. White Seabass are considered an important commercial and recreational fish species in both countries (Thomas, 1968). Although landings have fluctuated widely over time, U.S. management regimes have been in effect since 1930 and have included different gear restrictions, bag limits, closed seasons and minimum size limits (Vojkovich and Reed, 1983; Pondella and Allen, 2008). Fishing by the US fleet was permitted in Mexican waters until 1982 and comprised as much as 89% of the annual catch landed by the US commercial fleet (CalCOFI, 2009).

In Mexican waters the White Seabass fishery existed before the 1950s (Vojkovich and Reed, 1983; Erisman et al., 2010). During late spring and summer, White Seabass are considered a target fishery species along the western coast of the Baja California peninsula (Cartamil et al., 2011). In the northern Gulf of California, Moreno-Báez et al. (2012) identified White Seabass as one of 40 target fishery species. Little is known about the White Seabass population in the Gulf of California. However, Franklin (1997) provided evidence of a genetically distinct group from that found in the Pacific coast. Mexico does not have a specific regulatory strategy for this fishery resource such as minimum size limits, landing quotas for different fishing areas or a total allowable catch. The fishery is managed through non species-specific commercial fishing permits, and White Seabass are included in the broad category of coastal finfish species (*Escama*; SAGARPA, 2013). Species-specific catch statistics are unavailable for White Seabass. SAGARPA (2013) reported

* Corresponding author. Tel.: +52 646 175 0500.
E-mail addresses: aeromo@cicese.edu.mx (A.E. Romo-Curiel), sherzka@cicese.mx (S.Z. Herzka), ososa@cicese.mx (O. Sosa-Nishizaki), chugey@pier.org (C.A. Sepulveda), scott@pier.org (S.A. Aalbers).

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a total commercial catch for all croaker species in the Pacific off Baja California were ca. 1,800 metric ton (mt) for 2012, and White Seabass likely represent most of the catch. Data for recreational catches in Mexico are unavailable.

Studies on the biology of *A. nobilis* have been performed only in the northern portion of their range. Along the Pacific, the spawning period is from March to August with a peak in May or June (Allen and Franklin, 1992; Donohoe, 1997). White Seabass form seasonal spawning aggregations within shallow coastal waters and around nearshore islands (Thomas, 1968; Aalbers and Sepulveda, 2012). Donohoe (1997) estimated the daily growth rate of recently settled White Seabass and calculated that early juveniles remain in shallow nursery areas for two or three months. Older juveniles are concentrated in shallow areas close to the surf zone and their abundance decreases as a function of depth and distance from shore. Adults are found in schools and also as solitary individuals from the surf zone to a depth of 120 m and in habitats including sandy banks, rocky areas, kelp beds and artificial reefs (Vojkovich and Reed, 1983; Allen and Franklin, 1988; Donohoe, 1997).

Although the White Seabass is an important commercial resource of the US and Mexico, there are few growth estimates for this species with no studies assessing growth parameters across their range in the Pacific. The studies published to date are based on both otolith and scale analyses of fish captured in southern California waters. Clark (1930) generated the first estimates of age based on length frequency information from a limited number of individuals. Thomas (1968) conducted the first comprehensive age determination work based on the analysis of scales, but those estimates were later shown to underestimate age (CDFG, 2002; Williams et al., 2007). Based on unpublished data, the CDFG (2002) generated population-level growth rate parameters based on otolith ageing, and found that the maximum age and size were 27 years of age and 136.6 cm total length (TL). Fish of 71.1 cm TL (the current minimum size limit in California) were estimated to be three years old and the growth rate during the first few years was estimated to be 0.156 mm yr^{-1}. The CDFG (2002) data was based on primarily smaller individuals and examined a limited number of samples from age classes seven and older.

Williams et al. (2007) suggested that White Seabass growth rates vary annually relative to temperature; growth rates of juvenile White Seabass (1–4 years of age) were positively correlated with the higher sea-surface temperatures (SST) that are characteristic of El Niño Southern Oscillation (ENSO) conditions. This was observed despite the lower overall productivity of the region under ENSO conditions (Chavez et al., 2002). Temperature and food availability are among the most important environmental factors influencing growth rate in fishes. Within physiological limits, higher temperatures are reflected in fast growth rates, particularly in young fishes if food is not limiting (e.g. Brett, 1979; Otterlei et al., 2002; Folkvord et al., 2004; Neat et al., 2008). Somatic and otolith growth are highly correlated, and temperature has also been shown to have a strong influence on incremental ring widths and an otolith's growth rate (Brett, 1979; Mossegard et al., 1988; Árnason et al., 2009). Otolith-based age estimates and incremental (seasonal) ring width measurements have long been shown to provide a good approach for reconstructing the growth of fishes at the population (Campana and Neilson, 1985) and individual levels (Wilson and Larkin, 1980; Chambers and Miller, 1995). Consequently regional variations in growth could be an indicative of separate populations (Begg et al., 2001; MacNair et al., 2001; Yamaguchi et al., 2004).

Biogeographical breaks along the Pacific coast of North America have been shown to play an important role in determining population structure of coastal fish and invertebrate species. Punta Eugenia, located in the central part of the Baja California peninsula, is considered a transitional area in the California Current System (CCS) due to seasonal and latitudinal shifts in upwelling intensity and regional variation in the direction and intensity of coastal currents. There is also a well-documented latitudinal pattern in sea surface temperature (SST) along the Pacific coast of North America (Lynn and Simpson, 1987; Durazo et al., 2010). Some studies have documented the presence of biogeographical breaks in fish and invertebrate species north and south of Punta Eugenia (Horn et al., 2006; Kelly and Eernisse, 2007; Selkoe et al., 2007; Blanchette et al., 2008). To date, there are no studies that investigate the growth rate of this economically valuable species across their range, despite the oceanographic differences along the distribution of White Seabass in the Pacific.

The widths of otolith growth increments (daily rings and annuli) have been used to determine the somatic response to variations in habitat quality (Molony and Choat, 1990; Jones, 1992). The average values of the internal measurements of otoliths can vary significantly when comparing individuals of different stocks, although individual measurements do not necessarily allow individuals to be assigned to a particular stock (Pawson and Jennings, 1996); this tool has been used to help discriminate between stocks (Campana and Casselman, 1993; Begg et al., 2001).

This study used otolith-based techniques to estimate age and growth in White Seabass sampled off southern California and the northern and southern Baja California peninsula. We hypothesized that White Seabass collected along the Pacific coast may exhibit different growth rates throughout their distribution. Specifically, this work has focused on (1) strengthening age estimates for this species by examining a large range of adult sizes, (2) comparing population level growth rates among three locations, and (3) assessing individual growth trajectories through measurements of the width of annual growth rings.

2. Materials and methods

2.1. Sample collection

White Seabass were sampled between 2009 and 2012 from commercial and recreational fisheries in southern California (SC) and along the Pacific side of the Baja California peninsula (Fig. 1). Samples collected off Baja California were subdivided in two regions separated by Punta Eugenia (northern and southern Baja California, or NBC and SBC, respectively). Samples were primarily collected during the spring and summer months, which is when the fisheries operate in the US and Mexico. The SC samples were obtained from recreational fisheries that have a minimum size limit of 70-cm-TL (CDFG, 2002). In NBC White Seabass were caught by gill nets as well as by hook and line, which yielded a broader size range than for SC. In SBC commercial fishermen used gill nets and smaller fishes were caught than in SC and NBC. Fish total length and standard length (SL) were measured to the nearest cm ($n = 415$). Sagittal otoliths were extracted, cleaned and stored dry. For southern Baja California only SL measurements were taken, and a linear regression between TL and SL was generated to convert to total lengths ($TL = (SL + 2.54)/0.93$; $r^2 = 0.99$; $n = 135$).

2.2. Otolith ageing

Sagittal otoliths of White Seabass are very large, as in other sciaenids, and are unreadable if not sectioned. Whole otoliths were embedded in epoxy resin and two or three transverse sections 1 mm thick were cut through the central region along the dorsoventral plane with a slow-speed circular saw (Buehler, ISOMET^{TM}) to obtain a section that included the otolith core. Sections that included the core were polished using decreasing grit abrasive paper. A final polish with micro-cloth and 0.3-micron alumina