

QUEENFISH (*SERIPHUS POLITUS*) AND WHITE CROAKER (*GENYONEMUS LINEATUS*) LARVAL GROWTH PARAMETERS

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ABSTRACT

Larval *Genyonemus lineatus* and *Seriphus politus* collected using bongo frames fitted with 0.333 mm mesh nets between December 2003 and September 2004 off Huntington Beach, California, were examined to characterize their daily growth patterns. Samples from one net were fixed in a 4% buffered formalin-seawater solution while those from the other net were preserved in 70% ethanol. All formalin-fixed samples were transferred to 70% ethanol ~72 hours after collection. Growth was best described by a linear equation for *G. lineatus* ($L = -0.833 + 0.242A$; $R^2 = 0.84$) and a power function for *S. politus* ($L = 0.825 \times A^{0.647}$; $R^2 = 0.76$). Sufficient *S. politus* were available to analyze seasonal effects on growth rate; no significant differences were detected. No significant difference in the *S. politus* growth rate between preservation media was detected for samples collected on September 1, 2004.

INTRODUCTION

Life-history parameters of nearshore marine fishes are critical both in understanding fish species, and for their proper management through stock assessment modeling (e.g., Hill et al. 2006). Typically, population estimates and power plant entrainment/impingement impact analyses are based on demographic models (e.g. Adult Equivalent Loss and Fecundity Hindcasting) incorporating multiple life history parameters, such as maximum age, size and age at maturity, fecundity (annual or total lifetime), growth rate (adult or larval), stage-specific mortality/survival rate, and spawning seasonality (Goodyear 1978; Parker 1980; Jensen et al. 1982; Saila et al. 1997; Lo et al. 2005; Newbold and Iovanna 2007). Sufficient research effort into these parameters has been generally limited to commercially important species, such as northern anchovy, *Engraulis mordax*, and Pacific sardine, *Sardinops sagax* (Hunter and Macewicz 1980; Butler et al. 1993; Lo et al. 1995; Butler et al. 1996; Lo et al. 2005). Substantially less information is available for recreational and forage species (Cailliet et al. 2000).

Recent power plant once-through-cooling impact characterizations have been hindered by the aforementioned lack of life-history information (MBC and Tenera 2005²). The lack of basic parameters precluded nearly all of the demographic models in these assessments, thereby limiting the analysis to proportional models (Boreman et al. 1981; McCall et al. 1983). Problems with population assessments, including power plant impact characterizations, are most glaring when insufficient data are available for either demographic or proportional models. This becomes pertinent in southern California where white croaker, *Genyonemus lineatus*, and queenfish, *Seriphus politus*, each historically ranked among the most frequently encountered species during shallow (<60 m deep) open-water intake and discharge environmental monitoring (Allen and DeMartini 1983; Love et al. 1986; Stull and Tang 1996). Furthermore, larvae of both species have been commonly taken during nearshore southern California plankton sampling (Barnett et al. 1984; Lavenberg et al. 1986; Walker et al. 1987; McGowen 1993) including the shallowest California Cooperative Oceanic Fisheries Investigations (CalCOFI) stations located near the coast (Moser et al. 2001). Limited life-history information substantially hindered their management and analysis in environmental impact assessments despite their commonality in the area and apparent recent population declines (Miller et al. 2009). Prior, unpublished studies of this topic used samples collected in 1978 and found a linear relationship between age and growth as well as significant seasonal differences in both species (Barnett and Sertic 1980³). Therefore, this project was designed to reexamine their larval age and growth. The effect of formalin fixation on otolith-based age estimation was also evaluated given the availability of simultaneously collected samples which were initially exposed to ethanol or formalin.

²MBC Applied Environmental Sciences and Tenera Environmental, Inc. 2005. AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study Final Report. April 2005.

³Barnett, A. M. and P. D. Sertic. 1980. Growth rate of larval queenfish (*Seriphus politus*) and white croaker (*Genyonemus lineatus*) off San Onofre, California, in 1978. In summary report to W. Murdoch, Marine Review Committee, September 17, 1980.

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MATERIALS AND METHODS

All larvae were collected in a sampling grid centered offshore of Huntington Beach, California (33.64°N 117.98°W) during monthly sampling from December 2003 to September 2004 inshore of the 22-m isobath. Sampling consisted of oblique bongo net tows from the seafloor to the surface with 333- μ m mesh nets fitted with calibrated flowmeters conducted during four sampling events in each 24-hr sampling day (~1200, ~1800, ~0000, ~0600 hrs). The contents of one net from each deployment were fixed in a 4% buffered formalin-seawater solution while the other net was preserved in 70% ethanol. After survey completion, ethanol samples were archived and the formalin-fixed samples were washed and transferred to 70% ethanol for sorting and identification ~72 hours after collection. All formalin-fixed samples were sorted to remove, identify, and enumerate ichthyoplankton in support of MBC and Tenera (2005²). Preserved ethanol samples corresponding to formalin-fixed samples with comparatively high abundance of either target species were later sorted to provide samples free from formalin exposure.

Plankton shrinkage due to preservation was not quantified, so no adjustment to larval length was made. Furthermore, the technique utilized for the sample collection and processing was consistent with those used in all recent power plant once-through-cooling impact studies completed in the Los Angeles and Orange County areas (e.g. MBC and Tenera 2005²). Individuals of each species were measured by capturing digital images through a video stereoscope and processing them through image analysis to measure length (L) to the nearest 0.1 mm notochord length (prior to flexion) or standard length (post-flexion). Both sagittal otoliths were removed from each individual under stereoscope magnification using reflected light, mounted on a glass slide using immersion oil, and viewed under compound microscopy (400–1000 \times magnification) using transmitted, polarized light. Daily increments were counted from the core to the edge during two independent readings separated by a minimum of one week. Specimens lacking agreement between the two initial readings were read a third time for confirmation. If no confirmation could be made after the third reading, the sample was excluded. Based on laboratory-reared larvae and the assumption that sagittal otolith formation coincides with yolk-sac absorption, Barnett and Sertic (1980³) concluded otolith formation occurs at two days post-hatch in queenfish and five days post-hatch in white croaker. Final estimated ages in the current study incorporate these findings by adding the species-specific constant (2 or 5) to each increment count. Temporal differences in queenfish growth rate between June–July 2004 (n = 43) and August 2004 (n = 69) were compared using analysis of residual

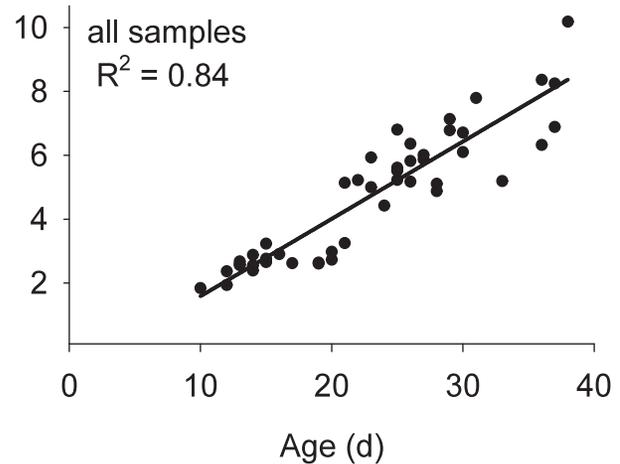


Figure 1. White croaker daily age and growth derived from increment analysis of 48 specimens collected between December 2003 and September 2004 offshore of Huntington Beach, California. The linear regression accounted for 84% of the variance ($R^2 = 0.84$): $L = -0.833 + 0.242A$.

sum of squares (ARSS) derived by non-linear regression (Haddon 2001). This technique was also used to test differences in derived growth curves based on preservation technique for queenfish collected on September 1, 2004. Similar analyses were not completed for white croaker due to the small sample size of formalin-fixed larvae. Lastly, the linear growth curves for all individuals combined, by species, for specimens collected in 1978 and 2004 were compared using a Mann-Whitney U test and the mean absolute difference between the two growth estimates was derived. The 1978 and 2004 mean annual sea surface temperature (SST) collected at the end of the San Clemente Pier in San Clemente, California was gathered from the Scripps Shore Stations Program database (SIO 2011). San Clemente Pier is located near the San Onofre sampling sites while the Newport Pier in Newport Beach, California is located closer to the 2004 Huntington Beach sampling sites. The questionable validity of the SST recorded at the Newport Pier during the 2004 sampling excluded its use in this analysis (M. Carter personal communication⁴).

RESULTS

White croaker (n = 48) ranged from 1.8 to 10.2 mm L and were primarily recovered from ethanol samples (n = 47), mostly taken in May and July 2004. Queenfish (n = 122) ranged from 2.5 to 10.5 mm L and were from both ethanol (n = 74) and formalin-fixed (n = 48) samples, mostly taken in July and September. White croaker specimens ranged in development from pre-flexion to post-flexion. No yolk-sac or transforming individuals were collected during the survey and therefore not available for analysis. The smallest individual was 1.84 mm L at an estimated age of 10 days while the largest speci-

⁴M. Carter, Scripps Institution of Oceanography, June 24, 2010

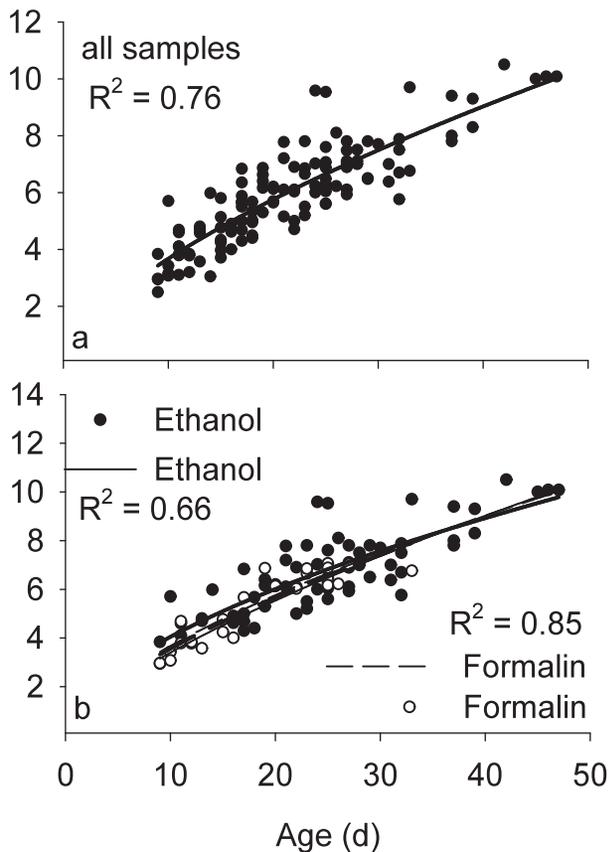


Figure 2. a) Queenfish daily age and growth derived from increment analysis of 122 specimens collected between December 2003 and September 2004 offshore of Huntington Beach, California. The non-linear regression accounted for 77% of the variance ($R^2 = 0.76$): $L = 0.825 \times A^{0.647}$. b) Daily age and growth of a subset of queenfish collected on September 1, 2004 and initially fixed in either 70% ethanol ($n = 74$) or a 4% buffered formalin-seawater solution ($n = 48$). The linear regression captured 66% of the variance in the ethanol-preserved distribution ($R^2 = 0.66$) and 85% of the variance in the formalin-fixed distribution ($R^2 = 0.85$).

men was 10.18 mm L at an estimated age of 38 days. Larval white croaker daily growth was best described by the linear relationship $L = -0.833 + 0.242A$ ($R^2 = 0.84$; fig. 1).

Queenfish ranged in size from 2.50 mm L at nine days old to 10.08 mm L for a 47-day-old individual. The majority of all individuals were between 3.00 mm L and 6.50 mm L. As with white croaker, no yolk-sac or transforming individuals were collected during the sampling offshore. Their growth rate gradually slowed with increasing length which resulted in it being best described by the power function: $L = 0.825 \times A^{0.647}$ ($R^2 = 0.76$; fig. 2a). No effect of seasonality was detected in the queenfish examined. Growth rates of queenfish hatched in June or July exhibited no significant differences in growth rate from those hatched in August (ARSS, $F_{1,114} = 1.82$, $p = 0.17$; fig. 3). The growth rates of 90 queenfish taken on September 1, 2004 were analyzed for differences in their derived growth based on

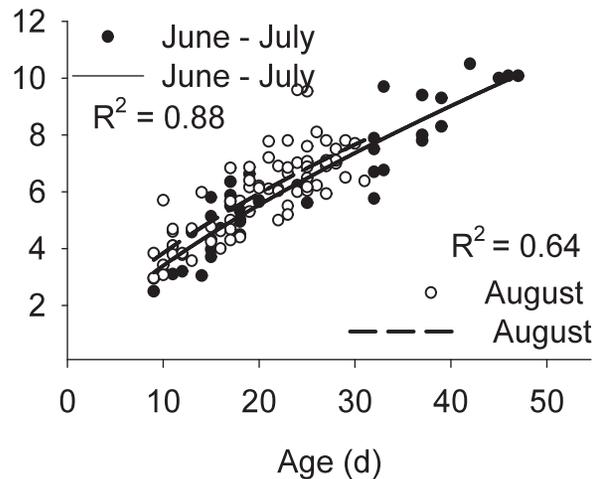


Figure 3. Queenfish age at length based on back-calculated hatch date. Non-linear regression captured 88% of the variance ($R^2 = 0.88$) in the distribution for those hatched in June and July ($n = 43$) and 64% of the variance ($R^2 = 0.64$) in the distribution for those hatched in August ($n = 69$). All samples collected offshore of Huntington Beach, California in 2004.

the initial preservative used. Twenty-five specimens were initially fixed in buffered-formalin with the remaining 65 fixed and preserved in ethanol. No significant difference in growth rates based on preservative type was detected (ARSS, $F_{1,88} = 2.43$, $p = 0.09$; fig. 2b).

The queenfish growth rates derived from samples collected in 1978 and 2004 consistently differed by two days (fig. 4a). Specimens collected in 2004 were larger at each age than those taken in 1978. This difference was significant (Mann-Whitney, $U = 6182.5$, $df = 121$, $p = 0.02$). The two larval white croaker growth rates differed by nearly 5 days (± 0.5 , standard error), on average, with the 1978 specimens older at each length in 81% of the specimens (fig. 4b). This difference was also significant (Mann-Whitney, $U = 837.5$, $df = 47$, $p = 0.02$). The mean annual SST at the end of the San Clemente Pier in 2004 was $\sim 0.9^\circ\text{C}$ warmer than in 1978.

DISCUSSION

The formation of daily increments on sagittal otoliths has been repeatedly confirmed in both laboratory-reared and wild-caught larvae (Victor 1982; Victor and Brothers 1982; Jones 1986; Peters and McMichael 1987; David et al. 1994). Larval daily growth patterns have been extensively studied in red drum, *Sciaenops ocellatus*, along the Gulf and Atlantic coasts (Peters and McMichael 1987; Cowan 1988; Comyns et al. 1989), but little research has been published in the primary literature on the Southern California Bight sciaenids. The current research is one of the first attempts to provide similar information on these sciaenids.

Both queenfish and white croaker exhibited steady somatic growth throughout the larval period between nine (queenfish) and 10 (white croaker) days old to 35

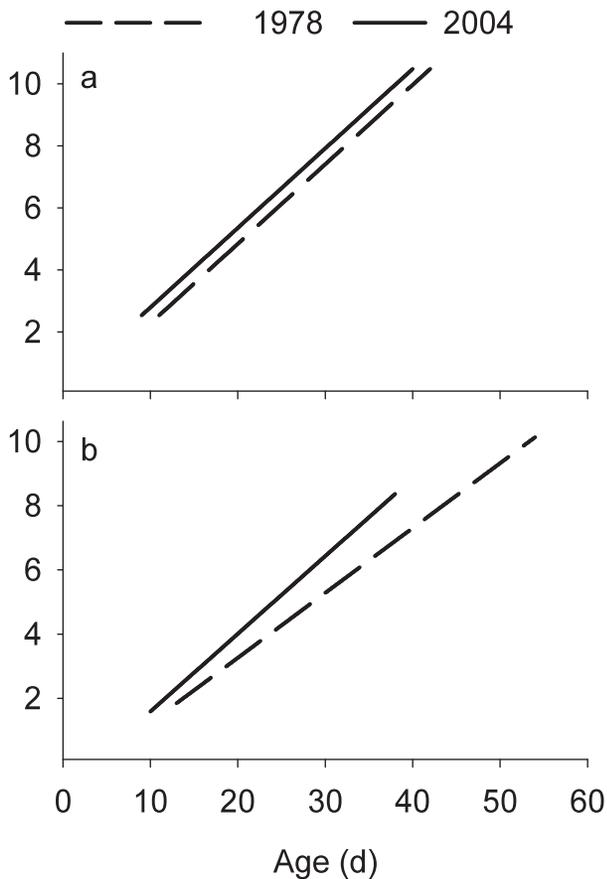


Figure 4. Linear descriptions of the larval growth rates for a) queenfish and b) white croaker based on samples collected in 1978 (Barnett and Sertic 1980³) offshore of San Onofre, California and in 2004 offshore of Huntington Beach, California.

days old or less. Larval growth rates in each species were well described by either linear or power functions with >75% of the variation captured by the model for each species. To date, no studies of the larval growth of wild-caught specimens of Southern California sciaenids have been published in the primary literature, thereby limiting the direct comparison of current results to other local species. A prior technical report by Barnett and Sertic (1980³) on this topic revealed some measured differences in the growth rates between the two sampling periods separated by over 25 years. In both studies, queenfish grew at a similar rate, but the more recent individuals were consistently two days older than was predicted by the Barnett and Sertic (1980³) model. This resulted in a significant difference between the two predicted ages at each length. Greater differences in growth rate were observed in the 1978- and 2004-collected white croaker (fig. 4). White croaker grew at a significantly faster rate in 2004 than the prior model predicted. Exact causes for this were outside the scope of this investigation, but the warmer SST likely contributed to this (Jones 2002). While the prior studies by Barnett and Sertic (1980³)

identified significant differences in seasonal growth patterns, no evidence of seasonal growth patterns in queenfish was observed in the current study. This is contrary to similar studies on sciaenids, especially among Atlantic- and Gulf-coast sciaenids (Jones 2002).

Butler (1992) reviewed preservation techniques used for specimens destined for larval otolith analysis and commented that while the exclusive use of ethanol was recommended (Brothers et al. 1976; Methot and Kramer 1979), several studies had successfully used specimens fixed in up to 10% buffered formalin. Direct comparisons by Kristoffersen and Salvanes (1998) found a 4% seawater-formalin solution resulted in less weight loss in preserved larval fishes and no significant changes to their otoliths. Our results agree with both Butler (1992) and Kristoffersen and Salvanes (1998) in that no significant difference was identified in the derived growth rates of queenfish taken on the same day but exposed to different preservatives (fig. 2). In fact, more consistent results were obtained from the formalin-fixed samples. The storage medium pH was not monitored, so potential etching due to acidic effects on the otoliths cannot be verified, but increments on the formalin-fixed queenfish otoliths were noticeably more defined than their ethanol counterparts. It should be noted, however, that no larval samples remained in the 4% seawater-formalin solution for greater than 80 hrs from the time of collection before being transferred to 70% ethanol.

These results (daily growth and preservative effects) help to advance the understanding of two fishes common to the Southern California Bight. Given their frequency in monitoring surveys and potential significance to nearshore ecology, greater understanding of their basic life-history parameters is critical for their effective management. Daily growth is one of the more commonly used parameters which, until now, was not readily available for these species. While daily growth for queenfish and white croaker does not, by itself, provide for the usage of demographic models, it nevertheless fills a critical gap. Furthermore, the confirmation that specimens fixed in a formalin-seawater solution are not unusable, but rather may be more resolvable for ageing, supports the revisiting of archived collections that may hold untapped scientific value.

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