# Age and growth of white croaker *(Genyonemus lineatus)* off Palos Verdes and Dana Point, California

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## ABSTRACT

Various studies have been conducted on the effects of contaminants on white croaker (*Genyonemus lineatus*) including reproductive impairment and damage to the liver; however, little information has been compiled about the effects of contaminants on their age and growth rates. This study describes the age and growth of white croaker from a contaminated site (Palos Verdes) and an uncontaminated site (Dana Point). White croaker were collected from both sites using a standard otter trawl from February, 1996, through May, 1998, and sagittal otoliths were analyzed to determine ages. No differences were found in the age and growth of white croaker between the two areas; however, older, larger fish were generally found at the Dana Point site and younger, smaller fish were generally found at the Palos Verdes site. Significant differences were observed in length-weight relationships between the two areas; however, these differences are most likely attributable to age differences for fish collected from each area. Recruitment, proximity to nursery grounds, fishing pressure, and body burdens of contaminants all potentially contribute to the differences in age structures of white croaker populations in the two areas.

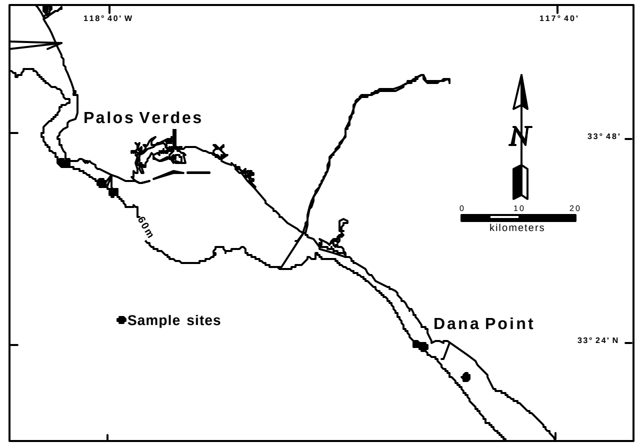
## INTRODUCTION

Large inputs of chlorinated hydrocarbon (CHC) contaminants, such as DDT and PCBs, were deposited into San Pedro Bay and the Palos Verdes shelf area between 1947 and the early 1970s, with smaller inputs in the 1980s (Mearns *et al.* 1991, MBC 1993). Municipal wastewater discharge on the Palos Verdes shelf has been the primary source of DDT and PCB compounds in the Southern California Bight. Although inputs of contaminants have declined since the early 1970s, a significant amount of contaminants are still present on the ocean floor in various areas. High levels of DDT and PCB compounds are found in several coastal species and have been shown to impair reproduction (Hose *et al.* 1989, Cross and Hose 1988). Fishes living in these areas could have been and may still be adversely affected by these high levels of CHCs.

White croaker (*Genyonemus lineatus*) are a common nearshore species that is abundant near wastewater discharge pipes and in degraded habitats (Ware 1979, Allen 1982); hence, they are subjected to environmental contamination from a number of point and nonpoint sources along the coast. In 1985, warnings were posted against the human consumption of this species off Palos Verdes by the California Department of Health and Human Services (Mearns *et al.* 1991). The occurrence of white croaker near contaminated areas has resulted in their being the subject of many contamination studies (Mearns and Sherwood 1977, Young *et al.* 1978, Gossett *et al.* 1983, Cross and Hose 1988, Hose *et al.* 1989, Pollock *et al.* 1991, SCCWRP 1992, Myers *et al.* 1994, SCCWRP 1994, Allen *et al.* 1996, and Gold *et al.* 1998). These studies have shown that white croaker in contaminated areas (e.g., Palos Verdes shelf) have higher levels of contamination (DDTs and PCBs) and a higher incidence of reproductive impairment (Cross and Hose 1988) and liver anomalies (Myers *et al.* 1994) than those in uncontaminated areas (e.g., Dana Point).

Many studies have found differences in the age and growth of fishes when exposed to different natural and anthropogenic stresses in their environment (Campana 1983a, Campana 1983b, Hales and Able 1995, Mortensen and Carls 1995); however, no studies have been conducted on the effects of high levels of contaminants on the age and growth of white croaker. Mortensen and Carls (1995) found a decrease in otolith growth and the number of increments produced in juvenile pink salmon exposed to crude oil; hence, it might be postulated that the growth of various fish species would be stunted in areas of contamination. However, the organically enriched sediments in contaminated areas (Ware 1979) might result in an increase in the prey of white croaker, which are benthic feeders, leading to increased growth in this species. The purpose of this study was to determine whether there are differences in the growth rates of white croaker sampled at a contaminated site versus an uncontaminated site. The Palos Verdes shelf was chosen as the contaminated area based on previous studies over a period of years that showed significantly higher levels of DDT and PCBs in white croaker sampled from this area than from other locations (Cross and Hose 1988, *Pollock et al.* 1991, SCCWRP 1994).

**FIGURE 1. Trawl locations for white croaker (*Genyonemus lineatus*) collected at Palos Verdes Peninsula and Dana Point.**




## METHODS

White croaker were collected from two locations: 1) Palos Verdes Shelf, California, and 2) Dana Point, California (Figure 1). The two locations represent the following conditions: 1) high contamination-high nutrients (Palos Verdes Shelf) and 2) no contamination-lower nutrients (Dana Point) (SCCWRP 1994, Bergen *et al.* 1998). Palos Verdes samples were collected from seven stations (51-61 m) from February through September 1996; and Dana Point samples were collected from four stations (45-67 m) from February 1996 through May 1998 (Table 1). Trawl fish were collected with 7.6-m head-rope semiballoon otter trawls with 1.25-cm cod-end mesh towed for 10 min. Fish were placed in plastic bags and returned to the laboratory, where they were frozen.

Upon thawing, each fish was measured to the nearest millimeter (mm) for both standard length (SL) and total length (TL). The whole fish was weighed and sexed. Gonads were removed and weighed to the nearest 0.01 gram (g). Fish were also examined for the presence of external anomalies such as parasites, tail erosion, lip papillomas, and missing pelvic fins.

After all external measurements were recorded, the sagitta were removed from each side of the head. They were cleaned, air dried, and stored in coin envelopes. The left sagitta was weighed to the nearest 0.0001 g using an analytical microbalance. Length and width measurements were taken to the nearest 0.001 mm using a microscope attached to a computer with an image analysis system (Optimus™ 1988).

Right otoliths were embedded in clear epoxy resin blocks. A thin dorso-ventral wafer was obtained from each otolith by placing each block with its otolith on a Buehler Isomet low speed saw. An initial cut was made using a single diamond-edge blade. The otolith was then moved so that a second cut could be made, producing a 0.5 mm wafer. The wafer was then glued to a microscope slide using Crystal Bond™ glue. Cooking oil was brushed over the surface to clear the wafer and allow for better reading.

Otoliths were read under a compound microscope at 4X with illumination from below. Each otolith was read three times, the first and second times about a month apart, and the second and third times about a week apart. When age readings did not agree for a given otolith, more readings were taken and the value of two coincident readings was accepted as the best estimate.

Allometric equations were calculated using $W = aL^b$, where W = weight in g, L = length in mm, and $a$ and $b$ are constants. Body weight minus gonad weight was used in this analysis due to potential differences in reproductive states among the fish. An analysis of covariance (Meyers 1990) was then performed on log-transformed length and weight data to determine differences in the slopes and intercepts of regression lines for location and gender. Mann-Whitney rank sum tests, t-tests, and Kruskal-Wallis one-way analysis of variance tests on ranks (Sokal and Rohlf 1995) were used to determine differences in body and otolith measurements between areas and gender. Von Bertalanffy growth equations ($L_t = L_\infty$ [1 - exp - k (t - $t_o$)], where $L_t$ = predicted length at time t; $L_\infty$ = theoretical maximum length; k = instantaneous growth rate; and $t_o$ = length at which the fish would theoretically have been at age 0; von Bertalanffy 1938) were computed using methods in Ricker (1975). Methods described in Allen (1976) were used to determine any differences in the equations.

**Table 1. Stations and locations of trawls conducted to collect white croaker from Palos Verdes and Dana Point.**

| Sample ID | Station | Date | Agency[a] | Station Coordinates[b] Lat N (dm) | | Long W (dm) | | Time | Depth (m) | Vessel[c] | No. of Fish |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Palos Verdes | | | | | | | | | | | |
| 1 | T4-200 | 2/14/96 | CSDLAC | 33 | 44.09 | 118 | 25.09 | 10:25 | 61 | Oc. Sent. | 4 |
| 2 | T5-200 | 2/14/96 | CSDLAC | 33 | 41.42 | 118 | 19.11 | 11:23 | 61 | Oc. Sent. | 1 |
| 3 | 9C | 4/22/96 | CSDLAC | 33 | 41.38 | 118 | 19.00 | 12:31 | 60 | Oc. Sent. | 2 |
| 4 | T4-200 | 8/05/96 | CSDLAC | 33 | 42.18 | 118 | 20.43 | 12:30 | 61 | Oc. Sent. | 68 |
| 5 | T5-200 | 8/05/96 | CSDLAC | 33 | 41.33 | 118 | 19.23 | 8:30 | 61 | Oc. Sent. | 52 |
| 6 | Zone1 | 9/03/96 | CSDLAC | 33 | 42.27 | 118 | 20.59 | 19:54 | 53 | Oc. Sent. | 79 |
| 7 | Zone2 | 9/03/96 | CSDLAC | 33 | 43.99 | 118 | 24.56 | 21:01 | 51 | Oc. Sent. | 97 |
| Dana Point | | | | | | | | | | | |
| 8 | L30 | 2/24/96 | OCMI | 33 | 27.20 | 118 | 43.96 | 20:30 | 67 | Sea Exp. | 3 |
| 9 | DP1 | 5/20/96 | OCSD | 33 | 27.14 | 118 | 43.76 | 11:45 | 45 | Early Bird | 16 |
| 10 | DP2 | 2/02/97 | OCSD | 33 | 24.31 | 118 | 38.92 | 8:50 | 60 | Early Bird | 57 |
| 11 | L30 | 5/07/98 | OCMI | 33 | 27.39 | 118 | 44.57 | 9:11 | 60 | Sea Exp. | 107 |

[a]Agencies
CSDLAC = County Sanitation Districts of Los Angeles County
OCMI = Orange County Marine Institute
OCSD = Orange County Sanitation District
[b]Station Coordinates
Lat N (dm) = Latitude North (degree minutes)
Long W (dm) = Longitude West (degree minutes)
[c]Vessels
Oc. Sent. = Ocean Sentinel
Sea Exp. = Sea Explorer

## RESULTS

### Body Measurements and Relationships

Fish collected from Dana Point were longer than fish collected from Palos Verdes (Table 2). Palos Verdes fish had smaller modes (140 and 180 mm TL) than Dana Point fish (170 and 260 mm TL) (Figure 2). Dana Point more closely reflects the plot for all data combined, which has similar modes (170 and 260 mm TL). The median of fish taken from Dana Point was significantly higher than the median of fish taken from Palos Verdes (Mann-Whitney Rank Sum, T = 58969.5, $p < 0.0001$). The median of females and males from Dana Point was also significantly higher than those taken from Palos Verdes, respectively (Kruskal-Wallis, H = 145.2, $p < 0.0001$).

Fish sampled from Dana Point weighed more than fish sampled from Palos Verdes (Table 2). The median body weight of Dana Point fish was significantly higher than the median weight of Palos Verdes fish (Mann-Whitney Rank Sum, T = 53912.5, $p < 0.0001$). Similarly, Dana Point female and male white croaker weighed significantly more than Palos Verdes white croaker (Kruskal-Wallis, H = 90.6, $p < 0.0001$).

Body weight increased at a faster rate in relation to the total length for Palos Verdes fish than for Dana Point fish; however, Dana Point fish were larger and weighed more overall (Figure 3). A multiple linear regression indicated that both the slopes and intercepts of the regression lines for location were significantly different ($p$ = 0.02 and 0.01); however, they were not significantly different for gender ($p$ = 0.39 and 0.93).

### Otolith Measurements and Relationships

Otolith lengths were larger overall for Dana Point fish (Table 3). The median length of Dana Point fish otoliths was significantly greater than that from Palos Verdes (Mann-Whitney Rank Sum, T = 59304.0, $p < 0.0001$). Female and male Dana Point fish had median otolith lengths that were significantly greater than those of Palos Verdes female and male fish, respectively (Kruskal-Wallis, H = 111.6, $p < 0.0001$).

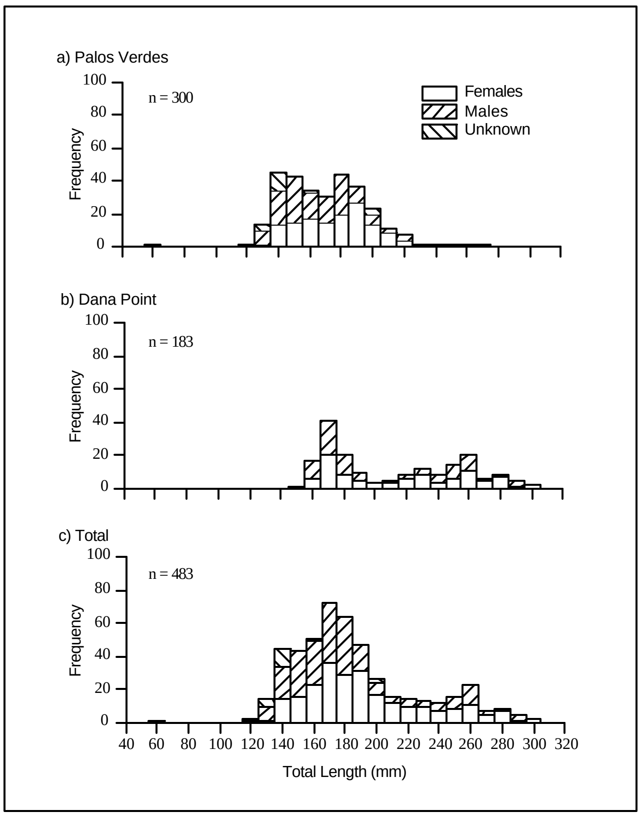
Otolith widths were also greater for Dana Point fish (Table 3). Dana Point fish median otolith widths were significantly greater than those of Palos Verdes fish (Mann-Whitney Rank Sum, T = 58675.0, $p < 0.0001$). The median widths of otoliths were significantly greater for both female and male Dana Point fish compared to those of Palos Verdes fish (Kruskal-Wallis, H = 109.3, $p < 0.0001$). Correlations between otolith lengths and widths were significant ($p < 0.001$) with r-values ranging from 0.90 to 0.94.

**TABLE 2. Total length and body weight (minus gonads) statistics for white croaker (*Genyonemus lineatus*) from Palos Verdes and Dana Point.**

| Location | Sample Size (n) | Total Length (mm) Median | Mean | Standard Error | Min. | Max. | Sample Size (n) | Body Weight (minus gonads) (g) Median | Mean | Standard Error | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Palos Verdes | | | | | | | | | | | | |
| Females | 142 | 180.0 | 179.3 | 2.12 | 135 | 249 | 142 | 71.4 | 74.8 | 3.00 | 28.4 | 208.5 |
| Males | 137 | 163.0 | 166.5 | 2.21 | 125 | 267 | 136 | 52.3 | 59.7 | 2.87 | 21.3 | 227.9 |
| Unknown | 21 | 138.0 | 142.8 | 6.30 | 64 | 201 | - | - | - | - | - | - |
| Total | 300 | 169.5 | 170.9 | 1.59 | 64 | 267 | 278 | 60.1 | 67.4 | 2.13 | 21.3 | 227.9 |
| Dana Point | | | | | | | | | | | | |
| Females | 99 | 220.0 | 216.6 | 4.27 | 150 | 297 | 99 | 127.9 | 131.9 | 7.33 | 41.0 | 304.0 |
| Males | 84 | 186.0 | 206.7 | 4.58 | 156 | 291 | 83 | 75.7 | 116.5 | 7.90 | 42.1 | 273.3 |
| Total | 183 | 204.0 | 212.0 | 3.14 | 150 | 297 | 182 | 103.7 | 124.9 | 5.39 | 41.0 | 304.0 |

Min. = Minimum; Max. = Maximum.
"-" = No data.

**FIGURE 2. Length-frequency plots of total length for white croaker (*Genyonemus lineatus*) caught off Palos Verdes, Dana Point, and both areas combined.**




Otoliths for Dana Point fish weighed more than otoliths for Palos Verdes fish (Table 4). The median otolith weight for Dana Point fish was significantly higher from that of Palos Verdes fish (Mann-Whitney Rank Sum, T = 61788.5, $p < 0.0001$). Both Dana Point female and male median otolith weights were significantly higher than those of Palos Verdes fish, respectively (Kruskal-Wallis, H = 145.2, $p < 0.0001$).

Otolith weights and lengths from Dana Point fish are generally greater than those of Palos Verdes fish (Figure 4). Otolith weight increases more slowly as length increases for Palos Verdes fish than for Dana Point fish. Slopes and intercepts for regression lines based on location were significantly different ($p = 0.03$ and $p < 0.01$, respectively); however, those based on gender were not ($p = 0.54$ and $p = 0.56$, respectively).

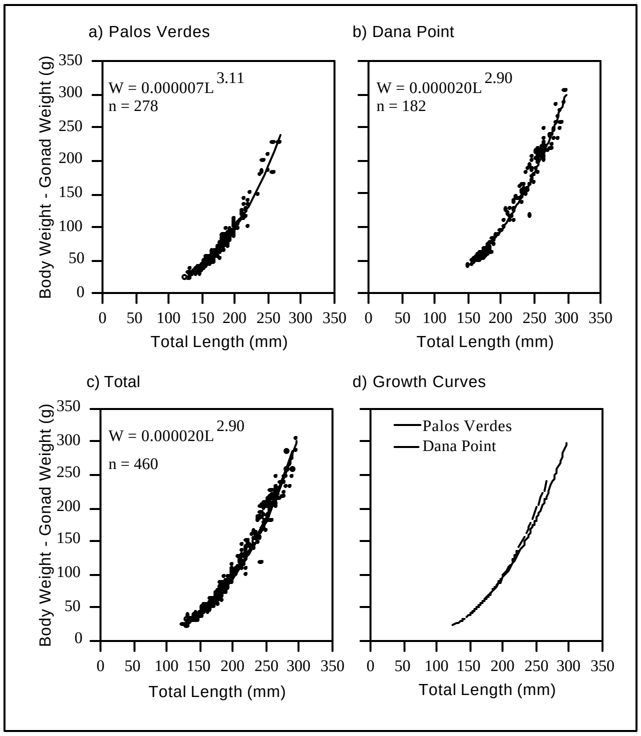
On average, Dana Point fish were older than Palos Verdes fish (Table 5). The median age of Dana Point fish was significantly higher than that of Palos Verdes fish (Mann-Whitney Rank Sum, T = 61851.0, $p < 0.0001$). Median ages of female and male Dana Point fish were significantly greater than those of female and male Palos Verdes fish, respectively (Kruskal-Wallis, H = 149.3, $p < 0.0001$).

Otoliths for Palos Verdes fish did not get as large as those for Dana Point fish (Figure 5); however, no differences were found in otolith growth rates at a given age. Growth curves for Palos Verdes fish do not approach the asymptote, whereas those for Dana Point approached approximately 91% of the asymptote at about age 13 (Figure 5). An analysis of covariance showed no significant differences in slopes and intercepts of regression lines for location or gender ($p = 0.43$ and 0.41, respectively) and hence no differences in otolith growth at any given age between the two sites.

## Body and Otolith Relationships

Palos Verdes fish did not grow as long as Dana Point fish; however, no differences were found in their body length growth rates at a given age (Figure 6). The theoretical maximum predicted total lengths of fish ranged from 298.8 for Dana Point females to 607.7 mm for Palos Verdes females. However, growth curves for Palos

**FIGURE 3. Body weight (minus gonad weight) versus total length for white croaker (*Genyonemus lineatus*) from Palos Verdes, Dana Point, and both areas combined. (Open circles = Palos Verdes; closed circles = Dana Point)**




Verdes females and males appear to be linear and, lacking data points for older fish, do not approach an asymptote. In contrast, the curves for Dana Point females and males, which include data points for older fish, approach approximately 95% of the asymptote at about 13 yrs (Figure 6). An analysis of covariance showed no significant difference in slopes and intercepts of regression lines for location or gender ($p = 0.36$ and 0.90, respectively); hence, no differences were found in body length and growth rates at any given age.

Otolith length and body length were similar for both Dana Point and Palos Verdes fish (Figure 7). Regression coefficients were high, with r-squared ranging from 0.92 to 0.96. The overall regression equation was OL = (0.04 * TL) + 1.85 (OL = otolith length and TL = total length) and indicates a slow rate of increase in otolith length with an increase in total length. An analysis of covariance showed that both slopes and intercepts were significantly different ($p < 0.0001$ for both) for the two locations; however, this difference is most likely attributable to the larger fish at Palos Verdes and smaller fish at Dana Point.

**TABLE 3. Otolith length and width statistics for white croaker (*Genyonemus lineatus*) from Palos Verdes and Dana Point.**

| | | Otolith Dimensions (mm) | | | | |
|---|---|---|---|---|---|---|
| Sample Location | Size (n) | Median | Mean | Standard Error | Min. | Max. |
| Otolith Length | | | | | | |
| Palos Verdes | | | | | | |
| Females | 141 | 8.43 | 8.37 | 0.083 | 6.60 | 11.14 |
| Males | 138 | 7.66 | 7.85 | 0.084 | 3.54 | 6.14 |
| Unknown | 21 | 6.66 | 6.69 | 0.267 | 3.40 | 9.32 |
| Total | 300 | 7.98 | 8.01 | 0.063 | 3.40 | 11.14 |
| Dana Point | | | | | | |
| Females | 99 | 9.82 | 9.66 | 0.149 | 7.47 | 13.29 |
| Males | 83 | 8.85 | 9.39 | 0.164 | 7.47 | 12.14 |
| Total | 182 | 9.39 | 9.53 | 0.110 | 7.47 | 13.29 |
| Otolith Width | | | | | | |
| Palos Verdes | | | | | | |
| Females | 141 | 4.472 | 4.502 | 0.0356 | 3.571 | 5.878 |
| Males | 138 | 4.157 | 4.268 | 0.0316 | 3.536 | 6.141 |
| Unknown | 21 | 3.856 | 3.879 | 0.1095 | 2.312 | 4.879 |
| Total | 300 | 4.301 | 4.351 | 0.0254 | 2.312 | 6.141 |
| Dana Point | | | | | | |
| Females | 99 | 4.909 | 4.961 | 0.0595 | 3.946 | 6.647 |
| Males | 83 | 4.586 | 4.814 | 0.0619 | 3.839 | 5.972 |
| Total | 182 | 4.799 | 4.894 | 0.0432 | 3.839 | 6.647 |

Min. = Minimum; Max. = Maximum.

## DISCUSSION

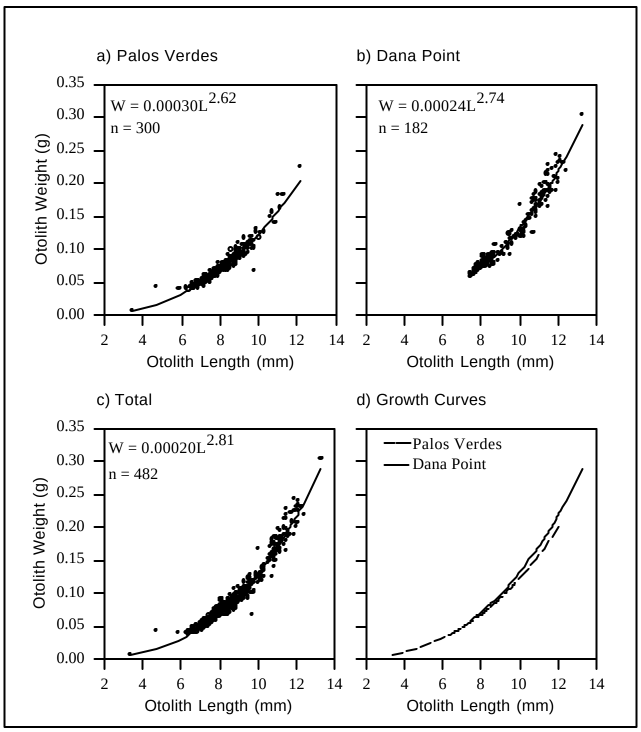
The purpose of this study was to determine any differences in the age and growth of white croaker sampled from a contaminated site (Palos Verdes) and an uncontaminated site (Dana Point). The results support the null hypothesis of no differences in age and growth between these two sites. White croaker from Palos Verdes and Dana Point grow at similar rates; however, white croaker from Palos Verdes appear to have a shorter life expectancy than those from Dana Point. White croaker generally live to be about 12 years old (Love *et al.* 1984); however, 15-year-old fish have been reported by others (Frey 1971, Love 1996) and from Dana Point in this study. Regression lines for body weight versus total length, otolith weight versus otolith length, and otolith length versus total length had significantly different slopes and intercepts, indicating that the growth relationships are different. However, because significantly younger, smaller fish were generally caught off Palos Verdes and older, larger fish were generally caught off Dana Point (medians of 170.9 and 212.0 mm, respectively), these regression lines most likely represent different parts of the same growth curve (growth

**TABLE 4. Otolith weight statistics for white croaker (*Genyonemus* lineatus) from Palos Verdes and Dana Point.**

| Location | Sample Size (n) | Otolith Weight (g) | | | | |
|---|---|---|---|---|---|---|
| | | Median | Mean | Standard Error | Min. | Max. |
| Palos Verdes | | | | | | |
| Females | 141 | 0.0765 | 0.0795 | 0.00211 | 0.0418 | 0.1628 |
| Males | 138 | 0.0619 | 0.0675 | 0.00221 | 0.0388 | 0.2253 |
| Unknown | 21 | 0.0436 | 0.0486 | 0.00451 | 0.0077 | 0.1064 |
| Total | 300 | 0.0672 | 0.0718 | 0.00153 | 0.0077 | 0.2253 |
| Dana Point | | | | | | |
| Females | 99 | 0.1190 | 0.1264 | 0.00526 | 0.0630 | 0.3028 |
| Males | 84 | 0.0920 | 0.1205 | 0.00599 | 0.0578 | 0.2421 |
| Total | 183 | 0.1065 | 0.1237 | 0.00395 | 0.0578 | 0.3027 |

Min. = Minimum; Max. = Maximum.

**FIGURE 4. Otolith weight versus total length for white croaker (*Genyonemus lineatus*) from Palos Verdes, Dana Point, and both areas combined. (Open circles = Palos Verdes; closed circles = Dana Point)**




curves excluding larger fish for Dana Point were similar to those of Palos Verdes).

Contaminants in white croaker do not appear to affect growth rates; however, given that no older fish were found at Palos Verdes, contaminants could affect their longevity. Even though DDT and PCB levels in the muscle tissues of white croaker tend to vary considerably among individuals and locations, Palos Verdes fish continue to have significant body burdens of DDT and PCBs (CSDLAC 2000) when compared to fish caught in other areas (SCCWRP 1994). Moreover, there has not been a consistent pattern of decline in the levels of these contaminants near the outfall since 1992 (CSDLAC 2000). It is not known if contaminant levels go up with age, and if so whether this effects their survival. Body burdens of contaminants tend to rise and fall seasonally as lipid stores fluctuate (SCCWRP 1987); however, no studies have been done to look at the overall health of white croaker as they age. Although fish around Palos Verdes appear to be in good health, the long-term effects of reproductive impairment (Cross and Hose 1988; Hose *et al.* 1989) and an increase in hepatic lesions with age (Myers *et al.* 1994) associated with higher contaminants may influence survival. Additional studies are needed to determine the long-term effects of chemical pollutants on these fish.

This study was not the first to examine age and growth of white croaker near Palos Verdes. Love *et al.* (1984) studied the age and growth of white croaker caught near Palos Verdes and reported similar results to those for Palos Verdes in this study. Both studies showed that fish caught near Palos Verdes were typically younger and smaller. Von Bertalanffy growth curves for Palos Verdes in this study and the Love *et al.* (1984) study were similar in that they never came close to approaching an asymptote (Table 5); hence, the maximum predicted lengths for fish were much higher than the maximum reported length of 41.4 cm (Miller and Lea 1972). However, when data from Palos Verdes and Dana Point are combined, the growth curves produced come closer to reaching an asymptote and the maximum predicted lengths (41.5 cm for females and 38.1 cm for males) are much closer to the maximum reported length of 41.4 cm. This result is probably attributable to the wider range of fish ages found in this study (1-15 yrs) compared to that in the Love *et al.* (1984) study (1- 12 yrs).

In this study, fish weight increased at a slower rate in relation to an increase in total length than that of the fish in Love *et al.* (1984) (Table 5). This difference might be attributable to the time of year and year that the sampling took place. Whereas Love *et al.* (1984) collected fish year round from 1978-81, most fish for the current study were sampled during the summer period from 1996-98. Also, the sample size was much larger in the Love *et al.* (1984) study than in the present study.

Otolith measurements and analyses are presented here for the first time. Differences were found in growth curves for otolith weight versus otolith length between Palos Verdes and Dana Point. However, this result is

**TABLE 5. Age statistics for white croaker (*Genyonemus lineatus*) from Palos Verdes and Dana Point.**

| | | Age (yrs) | | | | |
|---|---|---|---|---|---|---|
| Location | Sample Size (n) | Median | Mean | Standard Error | Min. | Max. |
| Palos Verdes | | | | | | |
| Females | 137 | 4.00 | 4.08 | 0.160 | 1 | 10 |
| Males | 136 | 3.00 | 3.29 | 0.159 | 1 | 12 |
| Unknown | 20 | 1.50 | 1.95 | 0.336 | 1 | 6 |
| Total | 293 | 3.00 | 3.57 | 0.113 | 1 | 12 |
| Dana Point | | | | | | |
| Females | 98 | 6.00 | 7.10 | 0.306 | 4 | 15 |
| Males | 83 | 5.00 | 6.80 | 0.346 | 3 | 14 |
| Total | 181 | 6.00 | 6.96 | 0.229 | 3 | 15 |

Min. = Minimum; Max. = Maximum.

**FIGURE 5. Von Bertalanffy growth curves for otolith length versus age in white croaker (*Genyonemus lineatus*) caught off Palos Verdes, Dana Point, and both areas combined.**

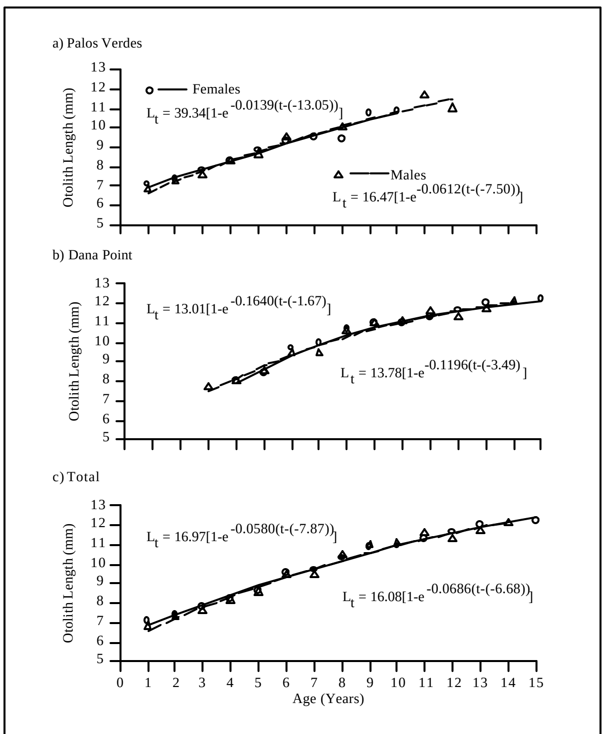
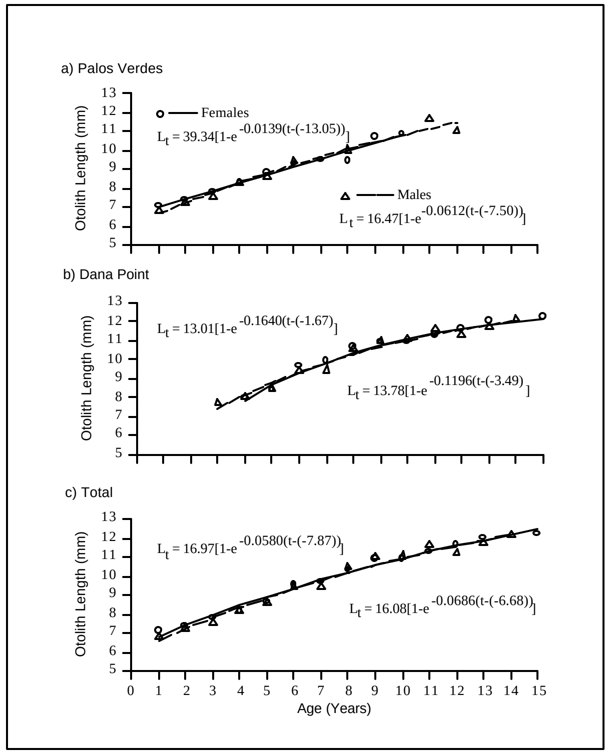



**FIGURE 6. Von Bertalanffy growth curves for total length versus age in white croaker (*Genyonemus lineatus*) caught off Palos Verdes, Dana Point, and both areas combined.**




believed to be attributable to the absence of older fish from Palos Verdes and younger fish from Dana Point. White croaker otoliths have been found in middens from Pliocene deposits in Long Beach, California (Love 1996), and hence otolith lengths/widths could more easily be used to determine the age structure of white croaker populations from earlier times.

Body and otolith measurements were significantly different and larger in every instance for Dana Point fish compared to Palos Verdes fish. Few studies have addressed the movement of white croaker along the coast; however, studies showing high levels of DDT in white croaker near Palos Verdes and low levels elsewhere indicate that there is little movement along the coast (Cross and Hose 1988, SCCWRP 1994). Hence, the measurements for Dana Point fish and Palos Verdes fish represent two different populations. A comparison of the length-frequency plots (Figure 1) and the von Bertalanffy plots (Figure 5) to determine strong recruiting year classes may lend some insight into the causes of differences in the size structure of the two populations. For example, length-frequency plots show bimodal distributions for both Palos Verdes and Dana Point fish, with the larger mode at 180 mm for Palos Verdes and 260 mm for Dana Point. These modes occur at approximate ages of 4-5 years for Palos Verdes fish and 9-10 years for Dana Point fish; therefore, recruitment might have been better about 5 years ago at Palos Verdes and about 10 years ago at Dana Point. Thus, the abundance of fish in these age classes would be greater, and would account for the size differential between these two areas. Another reason for smaller, younger fish being caught off Palos Verdes is the proximity of the Palos Verdes shelf to the Long Beach/ Los Angeles Harbor, where young white croaker are found (Allen and Herbinson 1991). Dana Point is in proximity to Dana Point Harbor; however, the size of this harbor is much smaller than the Long Beach/Los Angeles Harbor, and hence the recruitment of younger fish may be less.

Another factor influencing the size of fish collected at Palos Verdes could be fishing pressure. Although fishing of white croaker has been banned on part of the Palos Verdes shelf, Gold *et al.* [1998] reported that white croaker purchased from local fish markets had high DDT levels, and concluded that these fish were likely caught near the Palos Verdes "hot spot." However, it is not known for certain if these fish were caught near this area. If white croaker are commercially caught near Palos Verdes, larger, rather than smaller, white croaker, would more likely be caught and sold at these markets. Also, fishing in the deeper waters just outside the banned Palos Verdes areas would facilitate the collection of larger fish. Even if white croaker taken by commercial fishermen targeting other species were not sold, the incidental catch could be sufficient to affect the size structure of white croaker found off Palos Verdes.

**FIGURE 7. Otolith length versus total length for white croaker (*Genyonemus lineatus*) from Palos Verdes, Dana Point, and both areas combined. (OL = otolith length; TL = total length; open circles = Palos Verdes; closed circles = Dana Point).**

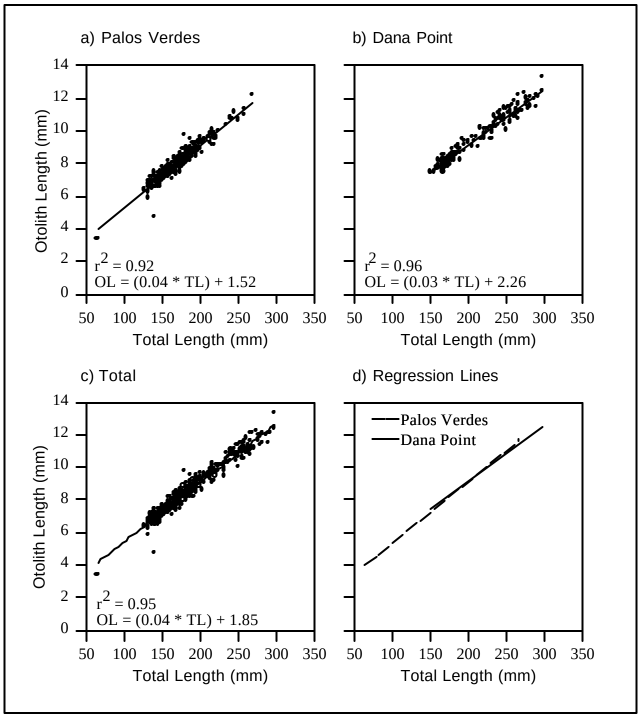



**TABLE 6. Comparisons of age and growth measurements for white croaker (*Genyonemuslineatus*) in this study and in Love *et al.* (1984).**

| | This Study Equation | n | Love *et al.* 1984 Equation | n |
|---|---|---|---|---|
| Standard Length vs. Total Length | SL = -5.11 + 0.87 TL | 483 | SL = 0.442 + 0.79 TL | 100 |
| Body Weight vs. Total Length | | | | |
| Females | $BWG = 0.000023TL^{2.88}$ | 241 | $BW = 0.0109TL^{3.0239}$ | 665 |
| Males | $BWG = 0.000017TL^{2.93}$ | 219 | $BW = 0.0111TL^{3.0114}$ | 581 |
| Total | $BWG = 0.000020TL^{2.90}$ | 460 | - | |
| von Bertalanffy | | | | |
| Females | $L_t = 41.54[1 - e^{-0.06(t + 5.70)}]$ | 235 | $L_t = 60.72[1 - e^{-0.037(t + 7.54)}]$ | 332 |
| Males | $L_t = 38.05[1 - e^{-0.07(t + 4.83)}]$ | 219 | $L_t = 59.17[1 - e^{-0.033(t + 8.66)}]$ | 250 |

TL = total length (mm); SL = standard length (mm); BWG = Body weight minus gonad weight (g); BW = body weight (g); $L_t$ = length at time t.

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