

AGE, GROWTH, AND MATURITY OF CABEZON (*SCORPAENICHTHYS MARMORATUS*) IN CALIFORNIA

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The age, growth, and maturity of cabezon (*Scorpaenichthys marmoratus*) from California were studied from July 2000 – July 2001. Ages were estimated using otoliths ($n = 641$) and validated using edge analysis. Errors in age estimates were calculated using average percent error, coefficient of variation, and index of precision. Growth was represented by the von Bertalanffy growth equation and statistically compared between sexes using Analysis of Residual Sum of Squares. Length and age at 50 % maturity was modeled for both sexes using a logistic curve. Females attained a larger size and grew slower ($L_{\infty} = 647.2$ mm TL, $k = 0.17$) than males ($L_{\infty} = 440.7$ mm TL, $k = 0.35$). Growth appeared to be rapid through age 4 for males and age 6 for females. The oldest male was 13 years old; the oldest female, 14 years. Growth curves were statistically different between sexes ($P < .001$). Length and age at maturity were estimated for males and females, with males maturing at 297 mm TL (1.9 yrs) and females at 337 mm TL (2.3 yrs).

Key words: age, cabezon, California, growth, maturity, *Scorpaenichthys marmoratus*

INTRODUCTION

The cabezon (*Scorpaenichthys marmoratus*) is the largest member of the family Cottidae, which contains over 300 species worldwide (Nelson 1984, O'Connell 1953). Cabezon can attain a length of 990 mm total length (TL) and mass of 6.8 kg. Cabezon occur from central Baja California to Sitka, Alaska, and from intertidal to depths of 76 m (Eschmeyer et al. 1983). They are demersal, solitary, and usually associated with reefs, boulders, kelp beds, or eelgrass (Lauth 1988). Cabezon are an important component of both the commercial and recreational fisheries in California and Oregon.

Because of their proximity to shore and ability to survive capture, cabezon are heavily targeted by the live-fish fishery. Started in the late 1980's, the live-fish fishery targets inshore species that can be held alive, i.e. rockfishes (*Sebastes* spp.), California halibut

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(*Paralichthys californicus*), California sheephead (*Semicossyphus pulcher*), and cabezon (Marx 2000). This fishery evolved from the demand for specialty foods in Asian markets and the live-fish commercial landings constitute a small, but significant, portion of total commercial finfish landings (McKee-Lewis 1996). Small boats, skiffs, and kayaks are used to set hooks and traps in water less than 30 m deep to target attractive “plate sized” fishes (about 1 kg). This “boutique” fishery started quickly and was difficult to monitor due to the mobility of the fishermen, remoteness of landing locations, and late offloading hours. Many of the fish are immediately transported to restaurants after being landed, which can make monitoring of offloads difficult. The rapid expansion of this fishery, encouraged largely from the high price-per-pound attained relative to dead-landed fish, along with the small target size (‘plate-sized’ fish preferred) began to concern fishery managers with the sustainability of current fishing conditions (McKee-Lewis 1996). Unfortunately basic biological data is lacking for many of the nearshore species targeted in the live-fish fishery, thereby increasing management uncertainty.

Although average cabezon commercial live-fish fishery landings have decreased in recent years, they remain an important component of the live-fish fishery. From 1998-2000, annual cabezon live fishery landings in California averaged 131 metric tons (mt), but since 2000, landings have decreased to an average of 44.3 mt per year (R. Leos, California Department of Fish and Game, personal communication). This decrease in landings is a direct result of more restrictive management measures. Even with time and area closures, the allowable catch of cabezon in the California commercial fishery was exceeded between 2001 and 2005, resulting in early statewide fishery closures. Cabezon also have a long history of recreational removals as well, with average decadal catches of 69 mt, 60 mt, 83 mt, 123 mt, 85 mt, and 47 mt for the 1950s, 1960s, 1970s, 1980s, 1990s, and 2000-2008, respectively (Cope and Key 2009).

Because of concerns about potential over harvesting, particularly of smaller individuals by the live-fish fishery, cabezon were chosen as one of 19 finfish species for management under the California Department of Fish and Game Nearshore Fishery Management Plan. Interim commercial regulations increased the minimum size limit from 305 mm TL (established before 1990) to 356 mm TL in 2000. The size limit was further increased to 381 mm TL in 2001 (Cope and Key 2009) to protect immature individuals from capture in fishing. Additional management based on accurate life history information is needed to prevent overfishing and maintain cabezon populations. And, to gain insight into the population dynamics of cabezon resources, estimates of age, growth, and maturity are crucial to relating the scale of removals with the absolute scale of cabezon population size.

Two studies have been published to date on cabezon life history. Estimates of age, growth, and fecundity in California (O’Connell 1953) and Washington (Lauth 1987, 1988) are based on small sample sizes (age/growth, $n = 202$; fecundity, $n = 70$) and out-dated ageing techniques (e.g. reading whole otoliths). No formal validation of the age increments in otoliths has hereto been demonstrated. There are also no quantified maturity estimates to date, although O’Connell (1953) suggested that males mature one year earlier than females. Age, growth, and reproductive parameters can vary with latitude; therefore, it is advantageous that they be examined throughout a range to characterize site-specific differences.

This investigation was designed to re-evaluate age and growth estimates of cabezon in California, and provides estimates of first maturity. Objectives of this study were to: (1) validate periodicity of increment formation in otoliths; (2) describe age and growth parameters

of cabezon in comparison to published studies; (3) determine length and age at maturity of cabezon; and, (4) determine if any site-specific differences exist in growth parameters of cabezon in California.

MATERIALS AND METHODS

Cabezon ($n = 680$) were collected from the commercial and recreational fisheries throughout California from 1996-2003. Commercial samples were collected statewide from the live-fish fishery using various gear types including rod-and-reel, vertical line gear, and traps. Recreational samples were collected opportunistically from spearfishing tournaments north of Point Conception ($34^{\circ} 27'$ North latitude). Sex, total length (TL) to nearest millimeter, and weight to nearest 0.1 kg were recorded for most samples (Figure 1). Some fish had been eviscerated prior to sampling; therefore, sex, weight, and length data were not always available. When available, gonads were assessed for maturity, removed, and weighed to the nearest 0.1 g.

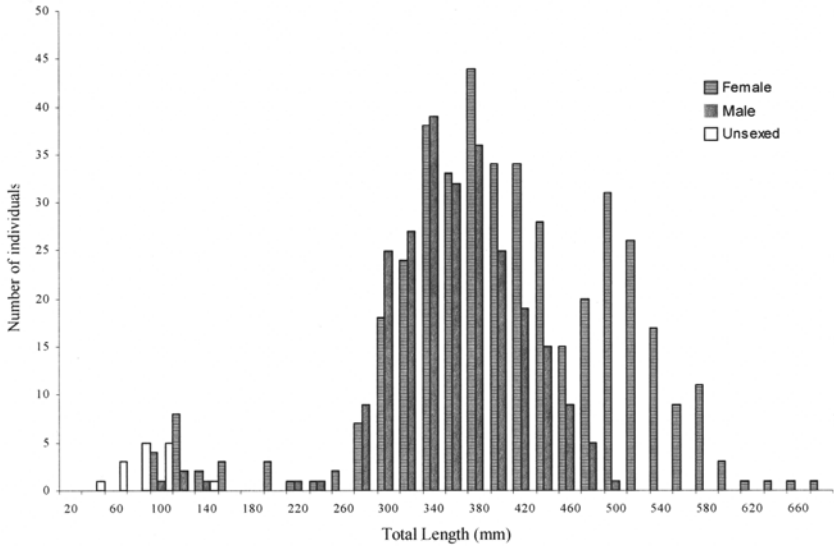


Figure 1. Length frequency distribution ($n = 680$) of cabezon (*Scorpaenichthys marmoratus*) collected in California from 1996 to 2002.

Sagittal otoliths were removed from each specimen, air-dried, and individually weighed to the nearest 0.001 g. Preliminary examination of whole otoliths revealed difficulty in interpreting growth zones. Although previous studies of cabezon age and growth (O’Connell 1953, Lauth 1987) used whole otoliths to estimate ages, growth zones were difficult to interpret in this study. Transverse thin sections (0.5 mm thick) were removed from otoliths for preliminary examination. In most cases, zones that were present on the otolith edge in transverse thin sections were not visible in whole otoliths. Based on this inability to see all zones in whole otoliths, transverse thin sections were chosen for this study.

Otoliths were embedded in fiberglass resin and sectioned using a Buehler low-speed Isomet saw. A transverse thin section (0.5 mm thick) was removed from the otolith nucleus and attached to a microscope slide using clear Cytoseal. Otolith sections were examined under reflected light, on a dark background and brushed with a thin layer of mineral oil to elucidate increments.

The relationship between the size of the otoliths and total length was determined by linear regression analysis (Brennan and Cailliet 1989, Zar 1999). Otoliths were measured to the nearest 0.1 mm across a pre-selected axis (maximum width) using an ocular micrometer.

Validation

Timing of increment formation was determined by recording if the otolith margin was opaque or translucent and expressing it as a percentage of the monthly sample. Sufficient monthly samples were not available for each age class for successive years. This situation made it necessary to combine samples from several years, locations, and ages. Inter-annual variability in patterns of otolith growth was assumed to be negligible (Horn 2002).

A chi-square contingency table was used to statistically test the periodicity of ring formation (Zar 1999). An expected distribution was created by using the observed number of samples with opaque edges and dividing them by 12 to evenly distribute the samples throughout each month.

Age Determination

The primary author read all otoliths using the previously described criteria and noted edge type as opaque or translucent. Ageing was repeated a minimum of three times, approximately two months apart, without knowledge of sex, length, date, or location of capture. Size-at-age data were examined from this study and compared to the results of O'Connell (1953). Females and males were plotted separately.

Precision Analysis

Error in age estimates was calculated using average percent error (APE; Beamish and Fournier 1981):

$$100\% \times \frac{1}{R} \sum_{i=1}^R \frac{|X_{ij} - X_j|}{X_j}$$

where R is the number of times each fish is aged, X_{ij} is the i th age determination of the j th fish, and X_j is the average age calculated for the j th fish. Coefficient of variation (CV, Chang 1982) was calculated as:

$$100\% \times \frac{\sqrt{\sum_{i=1}^R \frac{(X_{ij} - X_j)^2}{R-1}}}{X_j}$$

where R is the number of times each fish is aged, X_{ij} is the i th age determination of the j th fish, and X_j is the average age calculated for the j th fish. Index of precision (D; Chang 1982) was calculated as:

$$\frac{CV}{R}$$

where CV is coefficient of variation and R is number of times a fish is aged. Variability of APE and D was examined by plotting the range and mean of error for each age class.

An age frequency table was used to examine pairwise comparisons of age estimates from multiple reads by a single reader. Age bias plots are sensitive to both linear and non-linear biases, and were examined to determine consistency of age estimations by a single reader (Campana et al. 1995; Campana 2001).

Growth

Data on ages and lengths of males and females were fit to the von Bertalanffy growth equation (von Bertalanffy 1957):

$$L_t = L_{\infty} (1 - e^{-k(t-t_0)});$$

where L_t is total length (mm) of fish at any given age t (years), L_{∞} is the theoretical average maximum length (mm), k is the growth constant (yr^{-1}), and t_0 is theoretical age at size zero (yr). Parameters (L_{∞} , k , and t_0) were estimated for each sex using Iterative Growth modeling with Optimal Results (IGOR), a program developed in MATLAB®, which uses nonlinear parameter estimation (Cope nd). Gompertz and logistic growth models were also examined, but von Bertalanffy was chosen based on goodness-of-fit and the ability to compare results to previous studies.

Due to the non-linear formulation of the von Bertalanffy growth function, a general linear model of covariance could not be used. Therefore, we used a non-linear function to compare growth curves between locations and sexes. Analysis of Residual Sum of Squares (ARSS; Chen et al. 1992, Haddon 2001) compares the outcome of the hypothesis that all curves are coincident (i.e., each data set is effectively a sample from the same population) with the null hypothesis that all data sets are from independent populations (Haddon 2001). Although von Bertalanffy parameters (L_{∞} , k , and t_0) can be compared individually using a likelihood ratio, ARSS was chosen because it simply determines whether two or more curves are different, without examining which von Bertalanffy parameter is causing the statistical difference.

O'Connell's (1953) growth parameters were recalculated from original age and length data using IGOR. Original calculations used a Ford-Walford plot, a linear fitting technique, which provides a less precise estimate of growth. Recalculation of those data in IGOR should provide a comparable fit for the von Bertalanffy growth curve parameters.

Maturity

Reproductive maturity of gonads was determined by macroscopic examination. Using reproductive maturity stages modified from Nikolsky (1963), Holden and Raitt (1974), and Cailliet et al. (1986), sexual maturity of males and females was recorded as immature or mature. Length at maturity was estimated by calculating the proportion of mature individuals in 20-mm size intervals for each sex. Age at maturity was estimated by calculating the proportion of mature individuals in each age class for each sex. Calculations assumed equal weight of sample sizes, although number of individuals in each size or age class may have been unequal. Length and age at maturity was determined for males and females by fitting a logistic model (Gunderson et al. 1980):

$$P_x = 1 / (1 + e^{(a \cdot x + b)});$$

where P_x is proportion of fish mature at total length (mm) or age (yrs), a is theoretical size at age zero, x is the amount of growth per year, and b is age (yrs). The inflection point in the curve ($-a/b$) was the calculated length or age at 50 % maturity.

RESULTS

Validation

Determination of otolith edge type was not possible for all samples. It was especially challenging in older fish, which had narrow growth zones. Sometimes an age was assigned to an individual even though its marginal state could not be determined. When this occurred, data were used in growth parameter calculations, but not edge analysis (Horn 2002).

Edge analysis revealed that one pair of opaque and translucent growth zones was formed annually for individuals aged 6 years and less (Figure 2). Edge type could not be determined for individuals older than 6. A chi-square contingency table revealed a statistical difference between the observed distribution and a uniform distribution of opaque edge formation throughout the year ($P < .05$). This demonstrates a real difference between opaque and translucent edge formation and that the two edge types do not form in the same proportions for each month.

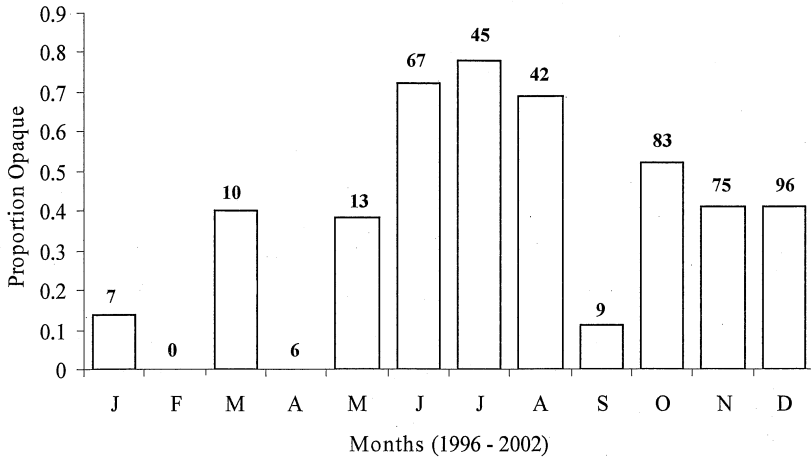


Figure 2. Histogram of percentage of cabezon (*Scorpaenichthys marmoratus*) otoliths collected from 1996 to 2002 that had an opaque edge present by month of capture. All age classes are combined for analysis.

Age Estimation

Ages were estimated from transverse otolith sections for 618 individuals (379 female, 239 male). The maximum age based on otoliths was 13 (males) and 14 years (females). Size-at-age data for individual sexes of cabezon were different between this study and O'Connell (1953). The mean total lengths and 95 % confidence intervals overlapped for few ages (Figure 3).

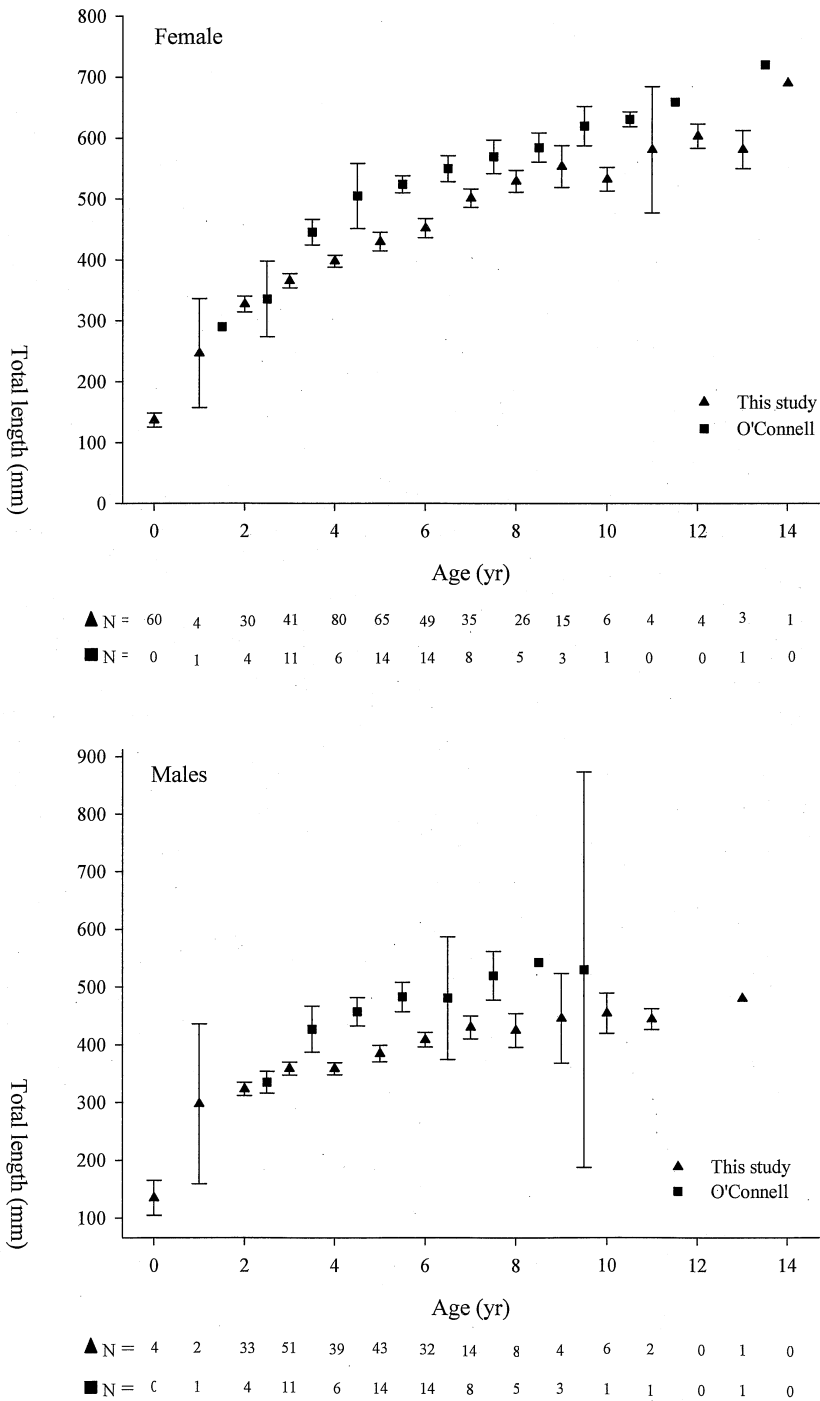


Figure 3. Growth curves for female and male cabezon (*Scorpaenichthys marmoratus*) in California (this study, triangle; O'Connell (1953), square), expressed as mean size at age estimated from otoliths. The vertical bars represent 95% confidence intervals, and "n" is the same size at each age for each study.

Precision Analysis

Comparison of APE and D revealed greater error in younger individuals, which decreased with increasing age. Individuals estimated 2 to 5 years old had the largest relative error and least relative precision in age estimates. Younger individuals (< 4 years old) grew fast and had broad opaque zones with numerous checks, which were sometimes difficult to differentiate from true annuli. Growth slowed at approximately 5 years of age, and annual growth zones became easier to interpret with fewer checks. Individuals aged 6 years and older displayed less error and more precision due to slower growth and more regularly spaced zones.

Age bias plots revealed all three individual readings to be fairly consistent with no systematic over- or underestimation of age. Age estimates of younger individuals had more variability, indicating those otoliths were more difficult to interpret than those of older individuals. Precision plots revealed that 87.0 % of age estimates were within ± 1 year; 96.3 % were within ± 2 years (Figure 4).

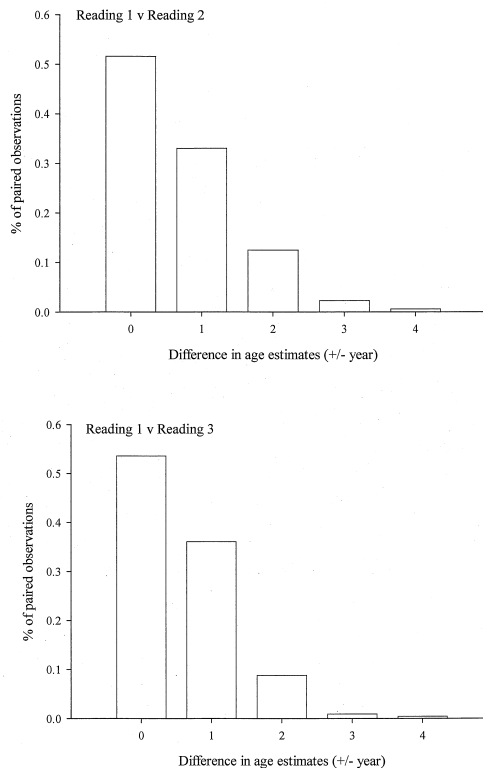


Figure 4. Differences in otolith annulus counts by comparing three independent counts of reading 1 vs. reading 2 and reading 1 vs. reading 3, (0 = no differences, exact agreement).

An age frequency table (Table 1) revealed no apparent bias in age determinations. Variability existed in age estimates for all age classes. All pair-wise comparisons of age estimates were consistent among examinations, with reading 1 and reading 3 displaying slightly more agreement between age estimates.

[illegible]

Age (yrs) estimated by:	Age (years)														Total	
by:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Read 1	Read 2															
0	32															32
1	1	3	6	6												16
2		2	35	14	3		1									55
3		1	12	54	17	8	1									93
4		1	1	22	63	16	9	1								97
5			1	6	24	62	20	12								125
6				1	6	18	35	11	3	1						75
7				2	2	2	8	24	11	8	3					60
8						1	7	4	16	7	3	1	1			40
9						1	2	3	3	6	5	2				22
10										3	6	3				12
11												3				5
12												1	1	1		2
13													3	1	2	6
14																0
	Read 3															
Read 1																
0	32															32
1		6	8	2												16
2		6	39	8	2	1										56
3			13	54	18	8										93
4			2	14	71	24	2									113
5			1	11	25	56	27	5								125
6				1	7	19	38	9	1							75
7				2	2	1	16	26	11	2						60
8							3	10	19	6	2					40
9						1	1	2	8	4	6					22
10									2	3	4	2	1			12
11											2	1	2			5
12													1	1		2
13												2		3	1	6
14																0
	Read 3															
Read 2																
0	32		1													33
1		4	2		1											7
2		6	36	8	4	1										55
3		2	20	62	16	5										105
4			3	13	71	22	7									116
5				8	24	53	16	6	1							108
6			1	1	8	21	39	9	3	1						83
7					1	8	18	23	3	2						55
8							6	9	16	2						33
9							1	2	12	6						25
10								3	4	3	4	1				17
11									1	1	3	2	3			10
12									1		1	2		1		5
13													1	2		3
14														1	1	2

Females attained a larger size and had a smaller growth coefficient ($L_{\infty} = 647.2$ mm TL, $k = 0.17$) than males ($L_{\infty} = 440.7$ mm TL, $k = 0.35$; Figure 5). Growth appeared to be rapid through age 4 for males and age 6 for females. The oldest male was 13 years old; the oldest female, 14 years.

Analysis of the residual sum of squares revealed statistically significant growth curves between sexes ($F = 54.43$; $df = 356$; $P < .001$). This result supports using separate growth models to describe cabezon growth in California as opposed to a combined sex curve.

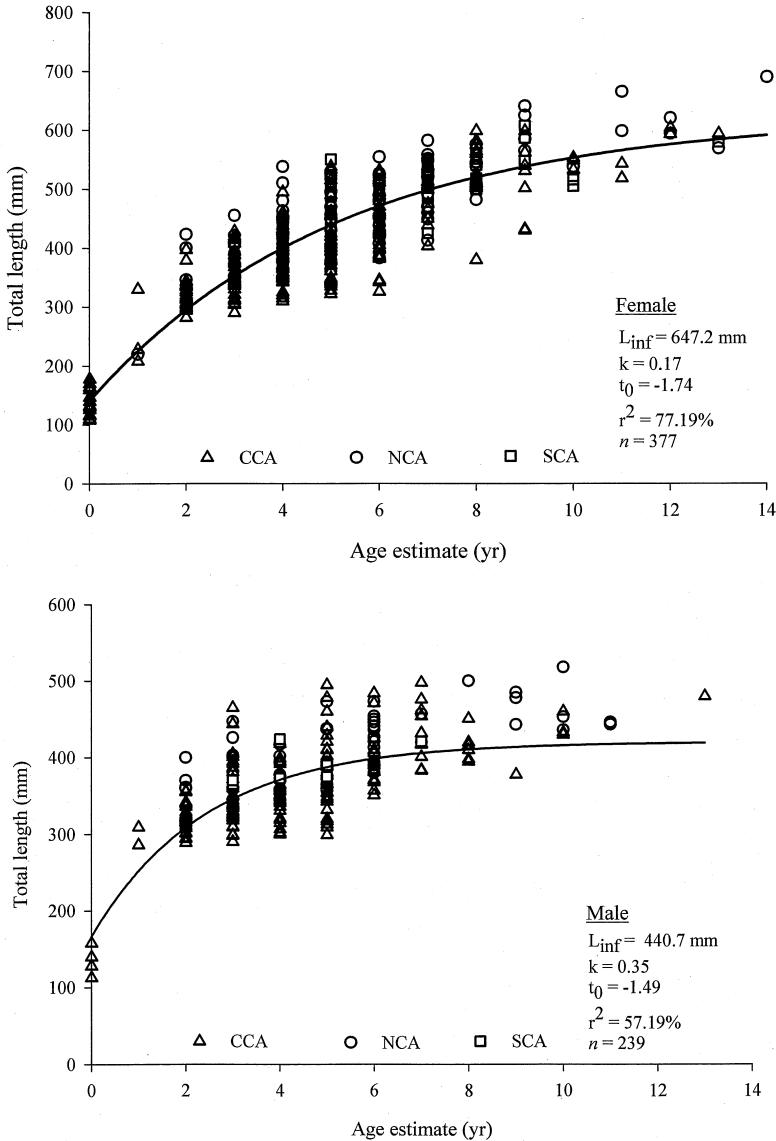


Figure 5. Raw data and fitted von Bertalanffy growth curves for female and male cabezon (*Scorpaenichthys marmoratus*) in California (CCA = central California; NCA = northern California; SCA = southern California).

Differences in site-specific growth among locations could not be statistically tested for either sex using ARSS due to missing data and unequal representation of populations. Examination of mean lengths at age for each sex among locations revealed no difference. Growth curves were, therefore, combined among locations.

Maturity Estimates

Length at maturity (in 20 mm size intervals) was estimated for 535 individuals (406 females; 129 males). Length at 50 % maturity was greater for females (337 mm TL) than males (297 mm TL; Figure 6). All fish greater than 475 mm TL were considered mature.

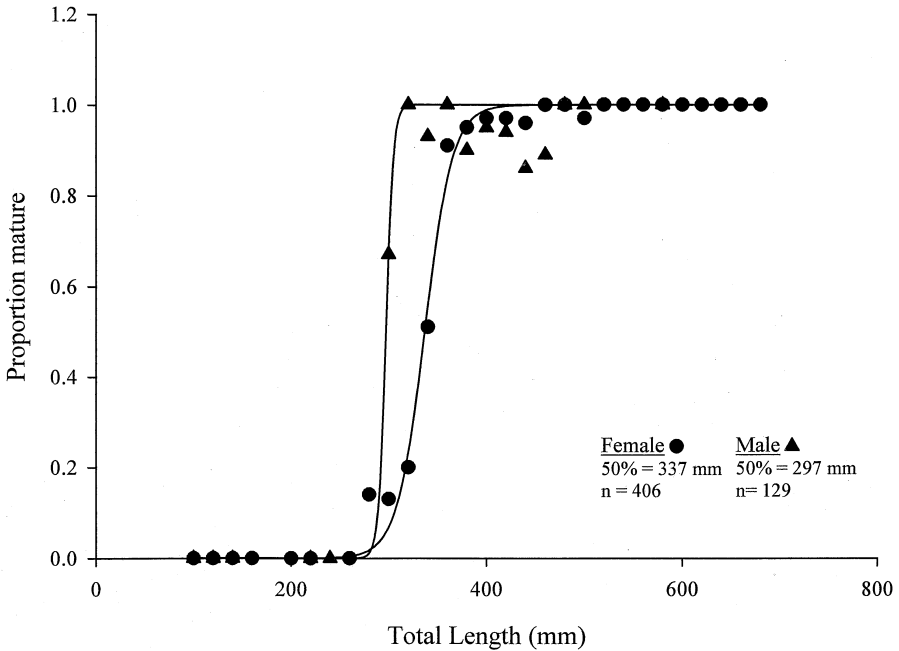


Figure 6. Logistic plot of proportion mature versus length of male and female cabezon (*Scorpaenichthys marmoratus*) in California. Graph assumes equal weight of samples although samples may be unequal.

Age at maturity was estimated by examining the proportion of mature individuals in each age class for each sex. Age at maturity was estimated for 505 individuals (373 females; 132 males). Age at 50 % maturity was greater for females (2.3 yr) than males (1.8 yr; Figure 7). Both sexes were mature by age 7.

DISCUSSION

Although more than 300 species of cottids exist worldwide, little is known about their life history. The few existing studies on cottid life history characteristics reveal relatively short lifespans and rapid growth (Daniels 1987; Mgaya et al. 1995). Although many taxa show a correlation across species between depth and longevity (Cailliet et al. 2001), cottids do not. There appears to be no trend of increased longevity with depth, location (inshore vs. offshore), or geographic location (Table 2).

Table 2. Summary of published literature on cottid age and growth, including maximum age, maximum length, maximum depth, and location of study (* = intertidal, ** = unknown).

Marine Species	Max. age	Max. length (mm TL)	Max. depth (m)	Location	Citation
<i>Artedius corallinus</i>	3	140	21	CA	Burge and Schultz, 1973
<i>Artedius harringtoni</i>	2	100	21	CA	Burge and Schultz, 1973
<i>Artedius lateralis</i>	3	140	13	CA	Burge and Schultz, 1973
<i>Clinocottus analis</i>	8 (M); 6 (F)	180	18	CA	Wells, 1986
<i>Clinocottus globiceps</i>	5	190	*	BC	Mgaya, 1995
<i>Clinocottus recalvus</i>	2	130	*	CA	Burge and Schultz, 1973
<i>Gymnocanthus pistilliger</i>	10 (M); 9 (F)	230	325	AK	Hoff, 2000
<i>Gymnocanthus tricuspis</i>	8 (M); 9 (F)	300	240	AK	Smith et al., 1997
<i>Hemilepidotus hemilepidotus</i>	7	510	275	CA	Burge and Schultz, 1973
<i>Jordania zonope</i>	5	150	38	CA	Burge and Schultz, 1973
<i>Leptocottus armatus</i>	3	460	156	CA	Burge and Schultz, 1973
<i>Myoxocephalus brandti</i>	8 (M); 9 (F)	300	**	SJ	Pachenko, 2002
<i>Myoxocephalus geneus</i>	1	n/a	**	ATL	Lazzari et al., 1989
<i>Myoxocephalus jaok</i>	12 (M); 15 (F)	460	550	SJ	Pachenko, 2002
<i>Myoxocephalus octodecemspinosus</i>	9	460	**	ATL	Morrow, 1951
<i>Myoxocephalus scorpius</i>	15	900	110	NF	Ennis, 1970
<i>Myoxocephalus stelleri</i>	8 (M); 9 (F)	400	**	SJ	Pachenko, 2002
<i>Nautichthys oculofasciatus</i>	2	200	110	CA	Burge and Schultz, 1973
<i>Oligocottus maculosus</i>	5	89	*	BC	Chadwick, 1976
<i>Oligocottus rubellio</i>	2	100	**	CA	Burge and Schultz, 1973
<i>Oligocottus snyderi</i>	1.5	89	*	CA	Freeman et al., 1985
<i>Orthonopias triacis</i>	2	100	30	CA	Burge and Schultz, 1973
<i>Ruscarius creaseri</i>	2	76	27	CA	Burge and Schultz, 1973
<i>Scorpaenichthys marmoratus</i>	13	990	76	CA	O'Connell, 1953
	6			CA	Burge and Schultz, 1973
	16 (M); 17 (F)			WA	Lauth, 1987
<i>Trigloporus quadricornis</i>	11	600	100	BB	Timola and Luotonen, 1986

AK = Alaska; ATL = Atlantic; BB = Bothnian Bay; BC = British Columbia; CA = California; SJ = Sea of Japan, NF = Newfoundland; SJ = Sea of Japan; WA = Washington [Length and depth information from www.fishbase.org]

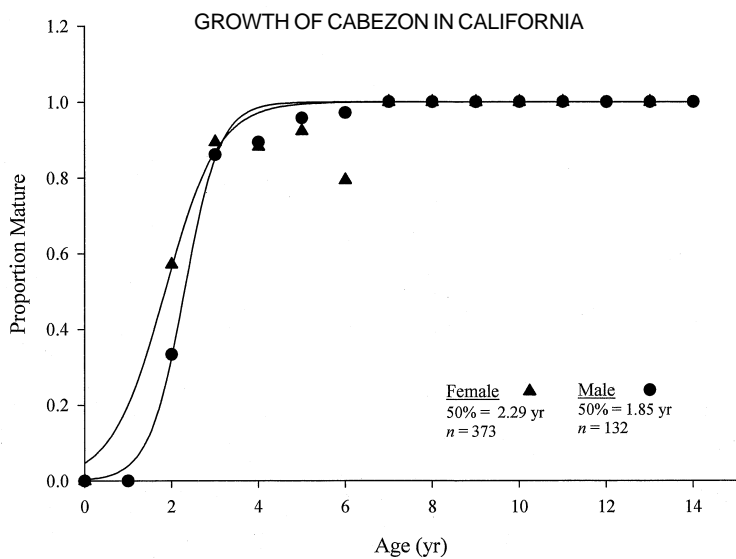


Figure 7. Logistic plot of proportion mature versus age of male and female cabezon (*Scorpaenichthys marmoratus*) in California. Graph assumes equal weight of samples although samples may be unequal.

The cabezon is the largest and only commercially important cottid in California. It has been fished heavily (commercially and recreationally) since the early 1990s and the statewide commercial fishery was closed early each year between 2001 and 2005 due to exceeding the allowable commercial catch. Such heavy fishing pressure creates a pressing need to reevaluate their life history characteristics to assure that the best available information is available for successful management of the cabezon fishery.

Size frequencies (TL mm) of cabezon sampled for this study were similar to the size frequencies presented by O'Connell (1953), with the exception of individuals less than 280 mm TL, which were only available in this study. Although cabezon are reported to reach a maximum total length of 990 mm TL (Eschmeyer et al. 1983; Miller and Lea 1972), specimens larger than 720 mm TL are uncommon in California and were not available for this study.

These results of this study suggest that ages obtained from whole otoliths underestimate cabezon ages in older individuals. In young fish, ages estimated from whole otoliths (O'Connell, 1953) were similar to those obtained from sections, but estimates became more dissimilar with increasing age. Females aged 3 and 4 years by O'Connell (1953) were estimated between 4 and 14 years in this study. One individual (595 mm TL), aged 4 years old by O'Connell (1953), would have been estimated at 14.7 years old based on von Bertalanffy growth parameters in this study. Another female (632 mm TL), aged 10 years old by O'Connell (1953), would have been estimated at 20.7 years old.

Comparison of size-at-age data between this study and O'Connell (1953) also support underestimation of cabezon ages. At any given age, the mean size in this study is smaller and, therefore, at any given size age estimation based on this study would be older. This difference in age estimation is probably due to the difference in ageing structures (i.e., whole versus sectioned otoliths) and the interpretation of fine zones on the otolith edge, and not to any changes in growth attributed to either fishing or environmental conditions.

The greatest ageing error observed in this study was among individuals aged 2 to 5 years. Younger individuals possessed numerous false annuli that could be difficult to differentiate from true annuli. Comparison of these results to those of O'Connell (1953) suggests that whole otoliths of young fish may be easier to interpret than thin sections because they lack false annuli that may only be visible in cross-section. This analysis revealed that age estimates were similar in younger individuals, thus demonstrating the use of whole otoliths to age young individuals is acceptable.

Validation of age estimates is essential in age and growth studies (Beamish and McFarlane 1983). Although edge analysis is the least preferred age validation method (Campana 2001), it was the only one available for this study. Other validation methods, such as marginal increment analysis and marginal increment ratio, were not performed because the edge type of sectioned otoliths could be difficult to determine (cabezon otoliths are disproportionately small for the size of the head). The outer increments were thin and measurements were not possible. Previous research (O'Connell, 1953, Lauth 1987) suggests cabezon do not live very long; therefore, more rigorous validation methods such as radiochemical dating are not possible.

Our estimates of L_{∞} are less than those recalculated values from O'Connell (1953; Table 3). Small individuals (less than 200 mm TL), which are necessary to anchor the growth curve and obtain realistic k values, were lacking in O'Connell (1953). Theoretical average maximum length (L_{∞}) was smaller for both sexes compared with those reported by O'Connell (1953). In this study, a calculated L value of 647.2 mm TL is suggested for females and 440.7 mm TL for males. Since L_{∞} is affected by the number of individuals in a size class, larger sample sizes of smaller individuals, combined with a lack of large individuals

of both sexes, decreased L_{∞} values in this study. This suggests that larger individuals were under represented in this study, possibly due to fishing removals.

Table 3. Comparison of cabezon (*Scorpaenichthys marmoratus*) growth parameters in California, including 95 % confidence intervals of each estimate.

		Female		Males	
			95 % CI		95 % CI
O'Connell (1953)	L_{∞}	760		604	
	k	0.09		0.17	
	n	70		35	
O'Connell (1953) recalculated	L_{∞}	678.3	619.5 to 737.1	535.8	499.3 to 572.3
	k	0.23	0.15 to 0.32	0.46	0.23 to 0.68
	t_0	-1.40	-2.45 to -0.34	-0.23	-1.21 to 0.75
Present study	L_{∞}	647.2	601.2 to 693.3	440.7	421.4 to 460.1
	k	0.17	0.14 to 0.20	0.35	0.26 to 0.44
	t_0	-1.7	-2.18 to -1.31	-1.50	-2.13 to -0.87
	n	377		239	

Size composition of both sexes was smaller overall in this study compared with O'Connell (1953). The largest female in this study measured 690 mm TL (14 years); the largest male was 518 mm TL (10 years). The largest female in the O'Connell (1953) study was 720 mm TL (13 years) and the largest male, 559 mm TL (9 years). The absence of large male individuals in this study may be a result of heavy fishing, especially since the onset of the live-fish fishery. Male cabezon are nest guards and would be more susceptible to capture during spawning season, and especially to spearfishing. Heavy fishing pressure could have selectively removed larger individuals of both sexes since O'Connell's (1953) original research.

Comparison of growth curves from O'Connell (1953) and this study were statistically and significantly different between females ($F = 33.53$, $df = 443$, $P < .001$) and males ($F = 28.39$, $df = 268$, $P < .001$). Statistical differences may have resulted from unequal sample sizes (this study, $n = 641$; O'Connell, $n = 105$), with a smaller size composition in this study.

Results from this study suggest that cabezon have a greater longevity than previously recorded. Based on the maximum reported size of 990 mm TL (Eschmeyer et al. 1983), it is probable that cabezon could attain ages of 20 years or more, but this is unlikely given the removal history.

This study provides the first quantitative estimates of age and length at maturity of cabezon in California based on sectioned otoliths. Our study suggests that the current minimum size limit of 381 mm TL (15 inches) may be inadequate for females. This size limit would only allow, on average, 44 mm of post-maturity growth (about 2 years) before fish are recruited to the fishery.

As discussed in the 2009 cabezon stock assessment (Cope and Key 2009), more work and effort are needed to increase our spatial understanding of biological parameters (growth, maturity, etc.) in California. For relatively sedentary species, such as cabezon, that range across significant zoogeographic boundaries but exchange limited recruits, localized biological differences in life history traits are probable. Regional management that takes into consideration these biological differences could be an important tool to consider in future management. Understanding differences in biological parameters could also help reduce uncertainty in future assessments

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