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Study of the Growth of the Green Jack *Caranx caballus* Günther 1868, in the Coast of Colima, Mexico

[1]Manuel Gallardo-Cabello, [2]Elaine Espino-Barr, [2]Arturo Garcia-Boa,
[2]Esther Guadalupe Cabral-Solís and [2]Marcos Puente-Gómez
[1]Instituto de Ciencias del Mar y Limnología, UNAM, Apartado Postal 70-305, C.P: 04510, México
[2]Centro Regional de Investigación Pesquera-Manzanillo, INP, Playa Ventanas s/n, Manzanillo, Colima 28200, México

Abstract: The age of the green jack *Caranx caballus* by the analysis of size frequencies in five age groups and with that of otoliths in four age groups is determined. The growth parameters of von Bertalanffy obtained with the frequency analysis were L_∞ = 55.38 cm, W_∞ = 3 841.65 g, k = 0.34, t_0 = -0.0084 and $A_{0.95}$ = 9 years. The results of the otolith lectures were L_∞ = 52.02 cm, W_∞ = 3 205.60 g, k = 0.362, t_0 = -0.085 and $A_{0.95}$ = 8 years. The growth parameters were compared with those of other species of the same genus. Data were also obtained for the gonadosomatic index which showed their maximum values during the months of June and October, which coincides with the season wherein data of the gastric repletion index increases and the values of the hepatosomatic index diminishes. The data obtained for the condition factor show their largest fluctuations during the period between January and August.

Key words: *Caranx caballus*, age, growth, length frequency distribution, otoliths, sagitta, asteriscus, longevity, biological indexes

INTRODUCTION

Caranx caballus (Fig. 1) is an American species of the Pacific Ocean, distributed from the coasts of Mexico to North of Perú (Chirichigno *et al*., 1982). In the State of Colima, Mexico, it is fished year round and the volume of its catch is only surpassed by the snappers of the Lutjanidae family (Cruz-Romero *et al*., 1996a, b; Espino-Barr *et al*., 2003). The green jack represents 6% of the total catch in the State but it is not registered in the fishing statistics of the rest of the country.

This species is captured incidentally during fishing of coastal pelagic species which are commercially important, such as the sierra *Scomberomorus sierra*. It can be captured with gill net, purse net, seine net, line and hook, spinning tackle or casting net. This species is used locally for human consumption and as bait. Together with other carangid species, it is commercially considered as a second and third class product, with a price ranging from 5 to 8 pesos per kilogram ($ 0.50 to $ 0.80 UDS), therefore it is an accessible food for low income population. The annual catch in the official statistics of the State from 1980 to 2002 varies between 9 and 250 ton, 93 ton average. The fishing effort is 3 000 to 28 000 annual trips. There is an increment in the catch of this species from September to December. The Capture per Unit of Effort (CPUE) is around 4.5 kg/trip, with few variations along the year, the maximum value in May.

Corresponding Author: Elaine Espino-Barr, Centro Regional de Investigación Pesquera-Manzanillo, INP, Playa Ventanas s/n, Manzanillo, Colima 28200, México
Tel: 01(314)33323750 Fax: 01 (314)33323751

Fig. 1: *Caranx caballus* Günther, 1868

Studies on ecology and dynamic of its population have been published by Ramírez-Granados (1977), Castro-Aguirre (1978), Chirichigno *et al*. (1982), van der Heiden (1985), Cruz-Romero *et al*. (1986, 1987, 1988, 1989 a, b, 1990, 1993), Espino-Barr (2000) and Gallardo-Cabello *et al*. (2006).

In terms of population dynamics, age determination is important to ascertain population structure and to analyze changes in its distribution and abundance throughout the year. Study methods on age are either direct or indirect. This latter consists on the analysis of the length frequency to identify polimodal curves corresponding to age groups. Direct methods consider hard structures on which the deposit of materials present a seasonal periodicity according to the availability of the food; these structures show zones of both slow and fast growth which help to determine the age and the calculation of von Bertalanffy (1938) growth parameters equation. On these bases we analyzed the length frequency distribution to obtain the average length for each age and the time of slow and fast growth ring formation in the sagittae. Characteristics of growth in length and weight and longevity were also studied. In addition, the values of the condition factor index, gonadosomatic, hepatosomatic and gastric repletion were obtained to better understand the growth phenomena.

MATERIALS AND METHODS

From January to December 2001, 50 individuals of *C. caballus* from the commercial captures of the coastal fishery were obtained monthly. The Standard Length (Ls), the total (Wt) and eviscerated weight (We), from the gonad (Wg), stomach (Ws) and liver (Wh) was registered for each organism. Only the standard and total length and total weight of over 200 individuals per month were taken directly in the sampling sites.

The data on length frequencies were analyzed with the FISAT program (Gayanilo *et al*., 1994) to estimate the average length related to the polimodal curves associated with each age group.

Average length data for each age determined with the sagittae and the asterisci otoliths by Gallardo-Cabello *et al*. (2006) were used to obtain the growth constants of von Bertalanffy (1938) equation. The observed lengths were: age 1 = 16.82 cm; age 2 = 27.78 cm; age 3 = 34.66 cm; age 4 = 40.27 cm.

The time of growth ring formation was determined analyzing whether the otolith border had a slow or a fast growth. In every case, the otoliths were observed by transparency with transmitted light. The opaque band indicated a fast growth whereas the hyaline band indicated a slow growth, in contrast to what occurs when light is reflected (Blacker, 1974).

There were no differences in the growth between sexes (Gallardo-Cabello *et al*., 2006).

The growth constants of von Bertalanffy (1938) equation, L_∞, k y t_o were obtained by the method of Ford (1933), Walford (1946) and Gulland (1964) and were adjusted by the convergent iterative method with the Newton algorithm in the Solver program of Excel (Microsoft, 1992).

The function $W = a L^b$ was used to obtain the weight-length relationship. The growth data for length and the weight-length relationship were used to obtain the weight at each age. The weight growth was obtained by substituting L_t and L_∞ by W_t and W_∞ in the von Bertalanffy (1938) equation. Taylor (1958 and 1960) equation was used to calculate the age limit or longevity (95% of the L_∞).

The values of the condition factor were obtained from the a data in the weight-length relation for total and eviscerated weight.

The gonadosomatic (GSI) and the Hepatosomatic (HSI) indexes were determined by the formulas described by Rodríguez-Gutiérrez (1992):

$$GSI = \frac{Wh}{Wt} * 100$$

where:
GSI = Gonadosomatic index
Wg = Weight of the gonad
Wt = Total weight of the organism

$$GRI = \frac{Ws}{Wt} * 100$$

where:
HSI = Hepatosomatic index
Wh = Weight of the liver
Wt = Total weight of the organism

The Gastric Repletion Index (GRI) was calculated by the method of Sierra and Popota (1988):

$$GRI = \frac{Ws}{Wt} * 100$$

where:
GRI = Gastric repletion index
Ws = Stomach weight
Wt = Total weight of the organism

RESULTS

Time of Growth Rings Formation

Figure 2 shows that the percentage of otoliths with fast growth bands is higher during autumn-winter, i.e., from September to February; while the percentage of otoliths with slow growth bands appear in spring-summer (March to August).

Length Growth

Analysis of length frequency: Table 1 presents the observed average lengths for each age group of *C. caballus* obtained by the length frequency analysis, by modal progression and by observation of otoliths sagittae and asterisci (Gallardo-Cabello *et al*., 2006); the values adjusted by the iterative method were also used. During the first year of life, *C. caballus* had the highest increment in length

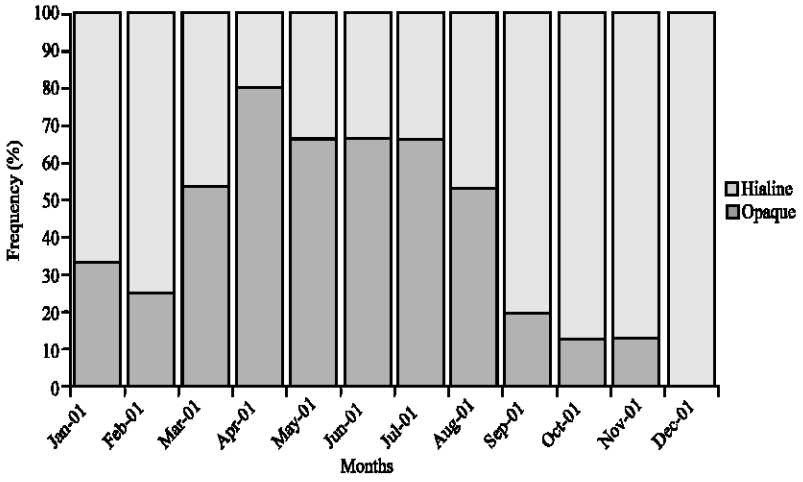

Fig. 2: Monthly frequency of the slow (hyaline) and fast (opaque) growth borders in the *C. caballus* sagittae

Table 1: Average of the standard length (cm) of each age group of *C. caballus*

	Length frequencies		Otoliths	
Age	Observed	Calculated	Observed	Calculated
1	15.86	15.849	16.82	16.88
2	27.26	27.243	27.78	27.54
3	35.37	35.353	34.66	34.97
4	41.14	41.125	40.27	40.14
5	45.25	45.234		

Table 2: Average length for each age of *C. caballus* in this paper and in Cruz-Romero *et al.* (1993)

Age	Length (cm) Cruz-Romero *et al.* (1993)*	Length (cm) Present study*
1	15.27	15.85
2	25.58	27.24
3	32.96	35.35
4	38.24	41.13
5	42.02	45.23

* Length frequencies

(15.85 cm) with the analysis of length frequency; thereafter the growth rate decreases: from age one to age two, 11.39 cm, 8.11 cm from age two to three, 5.77 from three to four, 4.11 from age four to five. Results of the analysis of the otoliths indicates that the growth decreases: 10.96 cm from age one to age two, 6.88 from age two to three and 5.60 from age three to four. Growth parameters of the standard length obtained from the otoliths analysis were: $L_\infty = 52.02$ cm, $k = 0.362$ and $t_o = -0.085$. Table 2 compares the values of the average length of each age with those calculated by Cruz-Romero *et al.* (1993). In both cases length determination was done with the analysis of length frequencies. The calculated data of this paper are higher in each age (0.5 to 3.5 cm).

Weight Growth

The value of the allometric index in the weight-length relation is $b = 2.91$ for total weight and $b = 2.92$ with eviscerated weight. Both values tend to be isometric (Fig. 3) ($t = 1.965$, $p>0.05$).

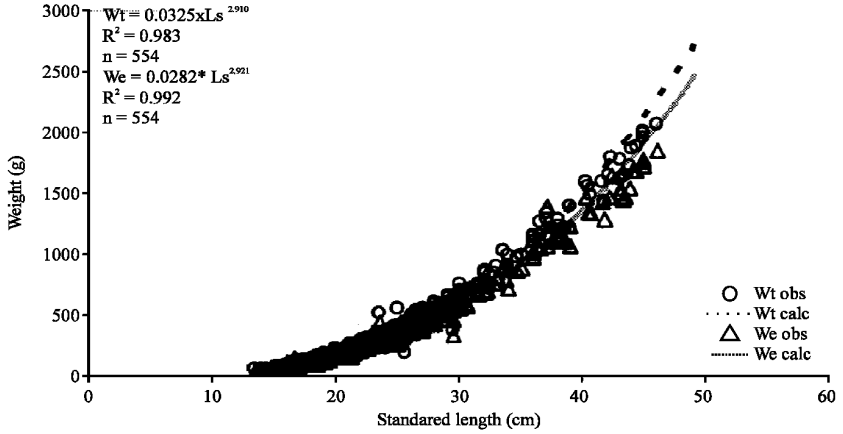

Fig. 3: Relation between standard length (Ls) and total (Wt) and eviscerated weight (We) of *C. caballus*

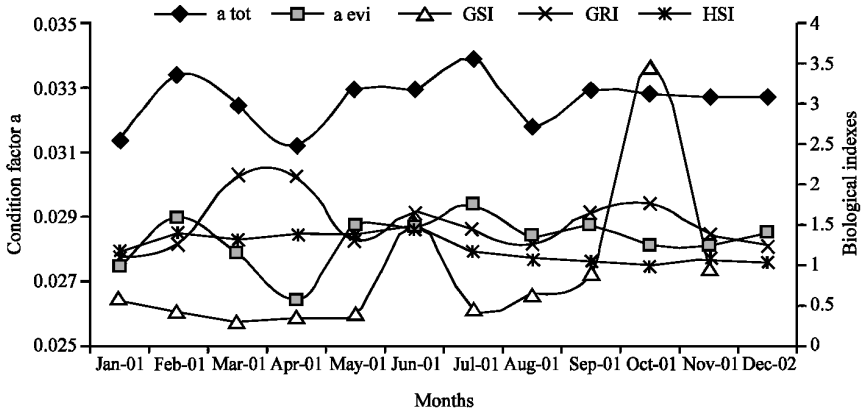

Fig. 4: Monthly values of the condition factor (a tot = total weight and a evi = eviscerated weight), of the Gonadosomatic Index in females (GSI), the Gastric Repletion Index (GRI) and the Hepatosomatic Index (HSI)

Theoretical Weight Growth

The values of theoretical weight growth in total and eviscerated specimens, for each age, obtained with length frequency data and otoliths are shown in Table 3. The values of the analysis of length frequency in weight are: Wt_{∞} = 3,841.65 g and We_{∞} = 3,486.65 g and Wt_{∞} = 3,205.60 g and We_{∞} = 2,905.04 g, for the results of the analysis of otoliths.

Longevity (Age $A_{0.95}$)

This species reached 95% of L_{∞} in 8.2 years which corresponds to an organism of 55 cm of length and an approximate weight of 3 kilograms.

Comparison of Growth Parameters Values of *C. caballus* with Other Caranx Genus Species

von Bertalanffy´s equation parameters for several species of the *Caranx* genus are shown in Table 4. Longevity information was calculated from the data reported by Taylor (1958 and 1960).

Table 3: Total and eviscerated individual average weight (grams) for each age group of *C. caballus*

	Length frequencies		Otoliths	
Age	Wt (g)	We (g)	Wt (g)	We (g)
1	101	90	121	108
2	488	439	504	453
3	1,041	940	1,009	910
4	1,616	1,462	1,508	1,362
5	2,132	1,931	1,941	1,755

Table 4: Values of the growth parameters for different species of the *Caranx* genus

Species	Author	Country	L_∞ (cm)	k	t_o	$A_{0.95}$
Caranx ruber	García-Arteaga and Reshetnikov (1985)	Cuba	56.00	0.100	-1.728	33.42
Caranx ignobilis	Sudekum *et al.* (1991)	Hawaii EUA	183.80	0.100	-0.097	30.06
Caranx melampygus	Sudekum *et al.* (1991)	Hawai, EUA	89.70	0.230	-0.044	13.07
Caranx caninus	Torres-Aguilar (2002)	Michoacán, Mexico	119.90	0.080	-1.572	39.02
Caranx caninus	Cruz-Romero *et al.* (1993)	Colima, Mexico	74.41	0.260	-0.250	11.52
Caranx caninus	Espino-Barr *et al.* (In Press)	Colima, Mexico	83.26	0.202	-0.283	14.53
Caranx bucculentus	Brewer *et al.* (1994)	Australia	53.88	0.305	*	9.82
Caranx crysos	Goodwin and Johnson (1986)	Norte del Golfo de Mexico, EUA	41.20	0.350	-1.17	9.73
Caranx sexfasciatus	Cruz-Romero *et al.* (1993)	Colima, Mexico	75.58	0.339	-0.063	8.90
Caranx caballus	Cruz-Romero *et al.* (1993)	Colima, Mexico	51.51	0.335	-0.03	8.97
Caranx caballus	This paper (length frequency)	Colima, Mexico	55.38	0.340	-0.008	8.82
Caranx caballus	This paper (otoliths)	Colima, Mexico	52.02	0.362	-0.085	8.20

* Not reported

Biological Considerations During the Growth of *C. Caballus*

Figure 4 shows the monthly values of indexes according to the condition factor (a), the Gonadosomatic (GSI), Hepatosomatic (HIS) and Gastric Repletion (GRI). The period of the highest spawning occurs during October and that of lesser spawning in June. The most active feeding period goes from September to February. The highest values of the RGI are during March-April and September-October.

DISCUSSION

Analysis of the otoliths showed a band of slow growth and another of fast growth are formed each year, which validates age estimate based on the number of rings in the otoliths of *C. caballus*.

Results of the analysis of length frequency with the application of the ELEFAN method (Gayanilo *et al*., 1994) and the growth ring determination of the sagittae and asterisci otoliths are very similar, which validate the parameters (Joseph, 1962). In addition, the data of average length of each age found by Cruz-Romero *et al*. (1993) were also similar. This indicates that the population of *C. caballus* has maintained its growth characteristics in the last decade, suggesting that this stock has reached its equilibrium and its biomass, due to the growth and recruitment and it decreases due to natural and fishery mortality. This in turn seems to indicate that the artisanal fishery in the coast of Colima does not affect the population biomass, a fact which coincides with the study of Espino-Barr (2000).

With respect of weight-length relation, Cruz-Romero *et al*. (1993) found an allometric growth index of 2.78; however in this study the value was 2.91, which is an isometric growth index.

Table 4 shows that the different species have a tendency whereby the smaller the k index is (0.08 to 0.26), the higher the L_∞ and the longevity, as occurs with *Caranx caninus*, *Caranx ruber*, *Caranx ignobilis* and *Caranx melampygus*. *Caranx caballus* belongs to the species of smaller size with a higher value of the k index and a lower L_∞ and longevity, as in *Caranx crysos* and *Caranx bucculentus*.

During the periods of higher spawning, the fat reserve index (HIS) diminishes, owing to a very high corporal waste of the fish (Nikolsky, 1963). Likewise, during the spawning periods there is a tendency to increase the gastric repletion index, showing an active feeding period that favors the formation of sexual products, both in quantity and quality. The effect of this higher feeding was observed two months later in the increments of the condition factor index for total and eviscerated weight.

The periods of more active feeding coincide with those when fast growth rings are formed in the sagittae, during September to February, i.e., in the rainy season (Observatorio de Manzanillo, personal communication; Espino-Barr, 2000), when more nutrients flow into the river which rushes to the coastal areas and into the sea. This also occurs during hurricanes season (Observatorio de Manzanillo, personal communication; Espino-Barr, 2000). These phenomena remove the bottom of the narrow Colima continental shelf, sending the nutrients to the surface of the ocean and increasing the production of plankton and of organisms that feed from it and form the food web. During this period the weight of the organisms increase and a faster growth in length of the larvae and juveniles takes place and recruit in the fishing area.

On the other hand, during the months of March-August (spring-summer) food availability decreases, the condition factor index diminishes and the slow growth ring are formed in the sagittae.

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