Age and Growth Studies of *Caranx hippos* (crevalle jack) from Trinidad Using Hard-parts

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ABSTRACT

Age and growth studies of the *Caranx hippos* (crevalle jack) in Trinidad have not been done despite its importance both commercially and recreationally. Age and growth information is fundamental to fisheries science as it one of the biological variables used in stock assessment. Age determination of *C. hippos* was based on whole and sectioned sagittae using the OPTIMAS image analysis software, and the resulting growth parameters were determined using the stock assessment software, FiSAT. Annuli on both the whole and sectioned sagitta were discernable, with each annulus comprising an opaque band and a translucent band. Sectioned otoliths generally yielded higher age estimates than whole otoliths. Ages ranged from young-of-the-year to 13 years and young-of-the-year to 10 for males and females respectively. *C. hippos* exhibits sexually dimorphic growth patterns with the resulting growth rates based on the von Bertalanffy growth model, L_t= 1044.0mm $(1-e^{-0.103(t+1.673)})$ and L_t= 709.42mm $(1-e^{-0.188(t+1.091)})$ for females and males, respectively.

KEYWORDS: Age and growth, sagitta, Trinidad

Estudios de la Edad y el Crecimiento de *Caranx hippos* (Crevelle Jack) de Trinidad Utilizando Partes Duras Realizados

No se han realizado aún estudios sobre la edad y el crecimiento de los *Caranx hippos* (crevalle jack) en Trinidad a pesar de su importancia tanto comercial como recreativa. Información sobre edad y crecimiento es fundamental para la ciencia de la pesca ya que es una de las variables biológicas utilizadas en la evaluación de la existencia. La determinación de *C. hippos* estuvo basada en *sagittae* entera y seccional utilizando el software de análisis de imagen OPTIMAS y los parámetros resultantes de crecimiento fueron determinados utilizando el software de evaluación de las existencias, FiSAT. Fueron visibles anillos tanto en la *sagitta* sectionada y completa con cada anillo formando una banda opaca y una banda translucida Otholiths seccionados generalmente produjeron estimados de una edad mayor que el otoliths complete. Las edades oscilaron desde el jóven –del-año hasta los 13 años y el –joven-del-año hasta los 10 años para machos y hembras respectivamente *C. hippos* exhibe un patrones de crecimiento sexualmente dimorficos con los por cientos de crecimiento resultantes basados en el modelo de crecimiento de

von Bertalanffy, L_t= 1044.0mm $(1-e^{-0.103(t+1.673)})$ y L_t= 709.42mm $(1-e^{-0.188(t+1.091)})$, para hembras y machos respectivamente.

PALABRAS CLAVES: Edad y crecimiento, sagitta, Trinidad

INTRODUCTION

The crevalle jack, *Caranx hippos* (Linnaeus, 1766), is a migratory, coastal species that is distributed worldwide at subtropical and tropical latitudes (Briggs 1960) In the West Central Atlantic region, it occurs throughout the Gulf of Mexico, and the Caribbean (Fischer 1978, Robins and Ray 1986). In Trinidad, it is one of the most abundant and commercially important by-catch species of both the demersal trawl catches and the artisanal gillnet fishery as well as is a target of the beach seine fishery. Referred to locally as the yellowfin cavalli, it is an important food fish with annual commercial landings of 190 mt, 346 mt and 238 mt for 1995, 1996 and 1997, respectively (Fisheries Division 2000). It is also important recreationally as a gamefish and is a target of several gamefish tournaments held throughout the year. Despite this commercial importance, no studies have been conducted on its life history or biology of this species in Trinidad waters.

Knowledge of age and growth is a life history aspect, which is fundamental to resource management. Age information forms the basis for calculations of growth rates, mortality rates and productivity, ranking it among the most influential of biological variables (Campana 2001). Hard-parts such as otoliths, vertebrae, spines and scales have been routinely used for providing age and growth information in fish stock assessments of temperate countries. However, in the wider Caribbean and in particular, the English-speaking Caribbean, there has been ad-hoc use of hard-parts for such age and growth studies. Age and growth studies for *C. hippos* are limited. A review of the literature cited only one study, Palko (1984), which evaluated the hard parts for age determination and selected the sectioned otolith as the preferred hard part for age determination.

Under the Caribbean Fisheries Regional Assessment and Management Program (CFRAMP), the Regional Fish Age and Growth Laboratory was established at the IMA in 1995. Its main objective was to provide age and growth information of commercially important fish species from the Caribbean through the analysis of hard-parts. Trinidad as a participating country identified *C. hippos* for an age and growth assessment. This research is the first of its kind being conducted for this species in the Caribbean. The specific objectives of this study were to provide age estimates from which growth parameter estimates can be derived as well as construct age length keys to determine the age composition of the population.

MATERIALS AND METHODS

A total of 327 samples of crevalle jack were collected from the artisanal and recreational fisheries. The Fisheries Division of Trinidad and Tobago collected samples from the artisanal fishery around the four coasts of Trinidad from the beach seine, gillnet and line fisheries during 1996 – 1997. In addition, the Institute of Marine Affairs (IMA) opportunistically collected large individuals from the gamefish tournaments held throughout the year from 1999 to 2003. For each sample fork length (FL) total body weight (Wt) and sex were recorded.

The three pairs of otoliths, the sagittae, lapilli and the asterisci were removed through the open-the-hatch method. They were cleaned ultrasonically in a 4:1 solution of water and 5 % sodium hypochlorite, rinsed in tap water and air-dried. Only the largest otolith, the sagitta was used for age determination and henceforth will be referred to as the otolith. Length measurements of whole, unbroken otoliths were recorded from rostrum to post-rostrum along the anterior-posterior axis and then weighed (± 0.001 g) using a Sartorius Balance. One of the pair of all otoliths, inclusive of broken and chipped otoliths where the focus was not damaged, were then placed in moulds and embedded in Spurr resin which hardened overnight in an oven at 60°C (± 1°). One or two transverse sections of the embedded otoliths incorporating the focus, were obtained using a Beuhler low speed saw. The resulting sections were then ground and polished by lapidary wheels using a series of 400, 600 and 800 Beuhler grit paper.

In some cases only one sagitta was sent, and therefore no distinction was made between left and right otoliths in age determination. Whole and sectioned otoliths were immersed in 95 % alcohol and viewed under reflected light for annulus interpretation using the OPTIMAS 5.1 image analysis software. Each annulus was interpreted as comprising an opaque band (white under reflected light) and a translucent band (dark under reflected light). Marginal annuli were also included in age counts. Both primary and secondary readers independently aged 100 % of the readable samples of whole otoliths and for the sectioned otoliths; the secondary reader aged approximately 80%. Age bias plots (Campana 1995) and percentage co-efficient of variation (C. V.) (Chang 1982) were used to assess the readers' bias and precision of age estimates. Based on the age bias plots, major discrepancies were reviewed and samples re-aged if necessary. Edge type analysis; monthly plots of the percent frequency of each edge type were used to evaluate the time of annulus formation. Plots of focus-to-annuli measurements along the distal surface of sectioned otoliths along the mid-portion of the dorsal lobe of the sectioned otolith were used to determine if annulus formation was consistent for different age group. All measurements were recorded using OPTIMAS 5.1 imaging software.

A fish length-otolith radius regression was calculated by linear regression of the $\log_{10}$ – transformed data using MINITAB, and used to derive mean back-calculated length at age for the various age groups. This together with observed mean length at age data for whole and sectioned otoliths were used to generate growth parameter estimates using age counts of the primary reader. These parameters, based on the von Bertalanffy growth model, were obtained using the FAO ICLARM Stock Assessment Tool (FiSAT) (Gayanilo et al. 1997). The von Bertalanffy growth model is described by:

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

where L_t = the mean length at age t; L_∞= mean asymptotic length; t_0= nominal age at which the mean length is zero; and K= rate constant that determines how fast L_t approaches L_∞.

Observed ages based on sectioned otoliths were used to generate age-length key for each sex. Aged fish were assigned to 50-mm length intervals and age distribution (as percentage) was then calculated for each size class.

RESULTS

Crevalle jack (n = 268) aged in this study ranged from 58 mm to 848 mm FL, of which 100 were young of the year (and ranged from 58 mm to 274 mm). Males (n = 120) ranged from 145 mm to 825 mm FL and females (n = 115) from 156 mm to 848 mm FL. The sexes of 33 individuals were unknown.

The whole otoliths when viewed under reflected light reveal a growth pattern of alternating broad translucent bands and opaque bands. Each annulus was assumed to comprise one opaque and one translucent band, Figure 1. Within each translucent and opaque bands there are several sub-annual growth zones making it a fairly difficult species to age. The clarity of the first annulus on the whole otolith was generally difficult to determine and even more so with younger fish. Sectioned otoliths have similar bands, Figure 2, and the position of the first annulus on the sectioned otolith was less difficult to define. The sectioned otoliths generally detected more annuli on their surfaces than the whole otoliths, and this difference between the whole and sectioned otoliths increased with age, particularly so, for the males, Figure 3.

Figure 1. Eight annuli on the whole otolith of the crevalle jack, *Caranx hippos* [472mm (FL), male] from Trinidad

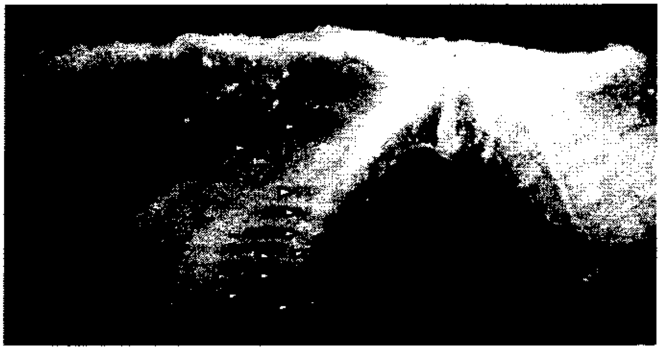

Figure 2. Ten annuli on the corresponding sectioned otolith of the crevalle jack, *Caranx hippos* [472mm (FL), (male] from Trinidad.

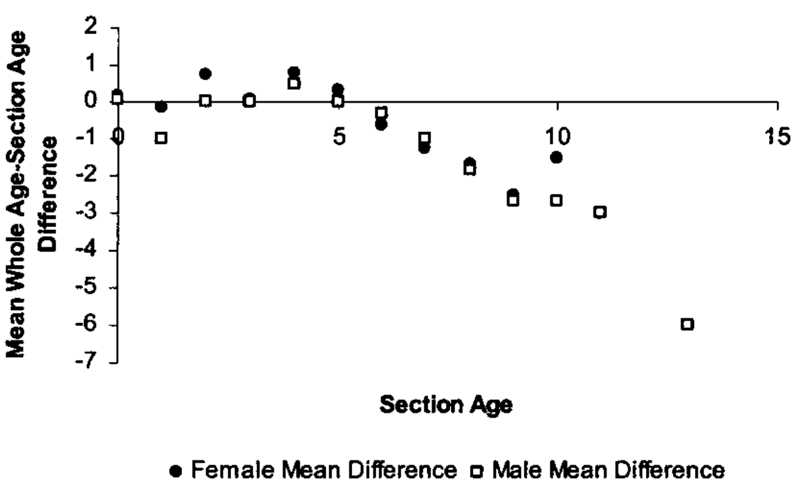

Figure 3. Mean difference between whole and sectioned otolith ages for each sectioned age group by sex of *Caranx hippos*

Validation of the periodicity of the annulus was attempted through edge type analysis, but due mainly to these sub-annual growth zones, the results were inconclusive over one year. However plots of focus-to-annulus measurements for males and females, show a single mode for each ring and a specific annulus location, which varied little with age, Figure 4 and 5. The overlap of these modes also increased with age.

The age bias plots between primary and secondary readers for whole and sectioned otoliths visually reveal very little bias, Figure 6 and 7. However the

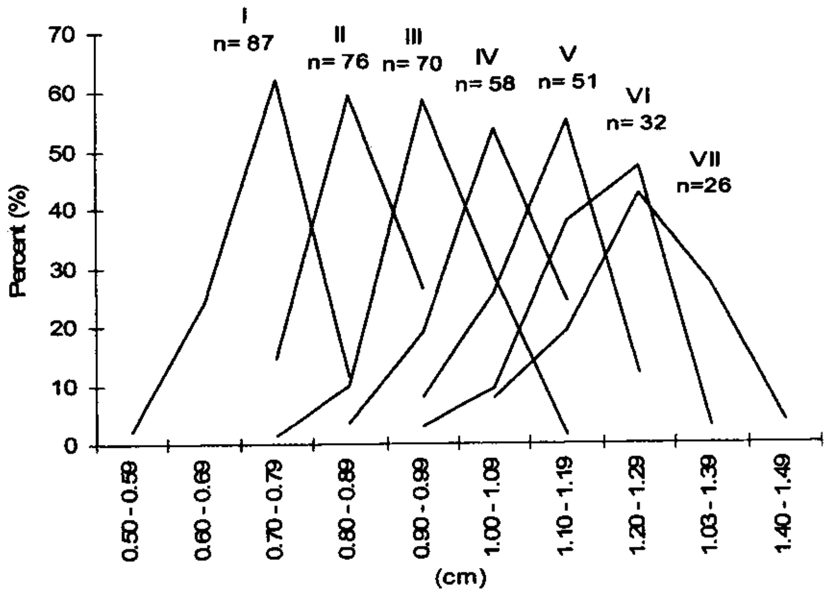

Figure 4. Distribution of focus-to annulus distances from sectioned otoliths of male *Caranx hippos*

The age bias plots between primary and secondary readers for whole and sectioned otoliths visually reveal very little bias, Figure 6 and 7. However the mean C.V. (18.8 %) for whole otolith is fairly high with most of the variation coming from the age I group for which it was fairly difficult to age. Determining the position of the first annulus on the section was less difficult and the corresponding C.V. (8.86 %) is more acceptable, closer to a suggested reference point of 5 % given by ageing laboratories, (Campana 2001).

Females ranged from YOY to 10 years while males ranged from YOY to 13 years. Age groups 5, 8 and 9 for males had a wider range of lengths of 400 - 700 mm, 400 - 700 mm and 400 - 750mm respectively, as compared to Age 6 and 8 for females of 500 - 650 mm and 400 - 800 mm, respectively. Also males had a wider range of ages within some of the length groups. For example within the length groups 400 – 450 mm and 450 - 500 mm, males ranged from 3 to 9 years and 4 to 10 years, respectively.

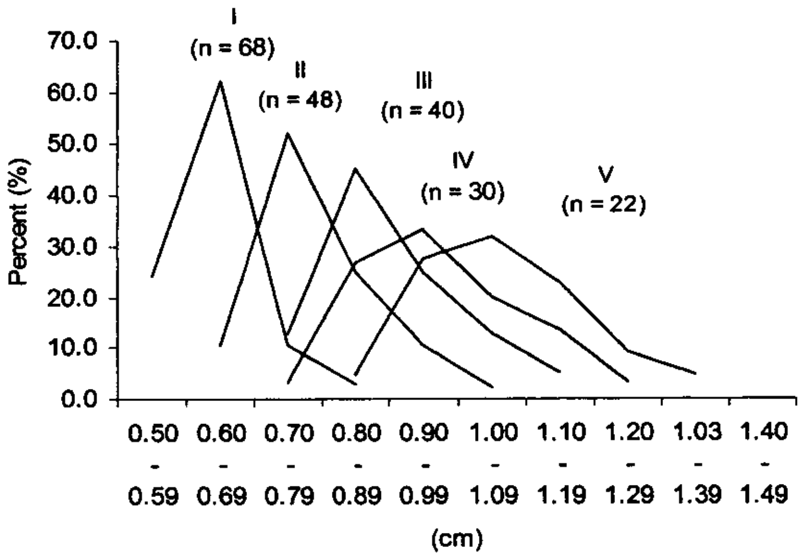

Figure 5. Distribution of focus-to annulus distances from sectioned otoliths for age groups I to V of female *Caranx hippos*

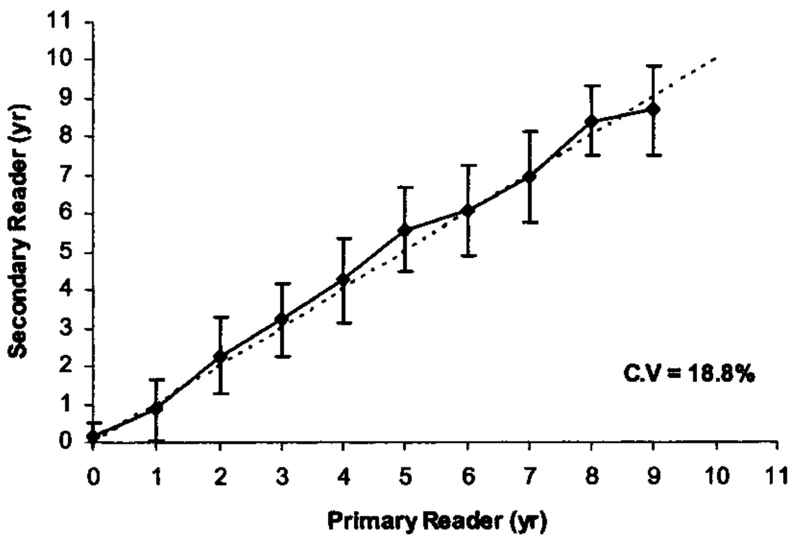

Figure 6. Age bias plot of secondary reader versus the primary reader for whole otoliths of *Caranx hippos*. Each error bar represents the 95% confidence interval about the mean age of the secondary reader. The 1:1 equivalence line is also indicated.

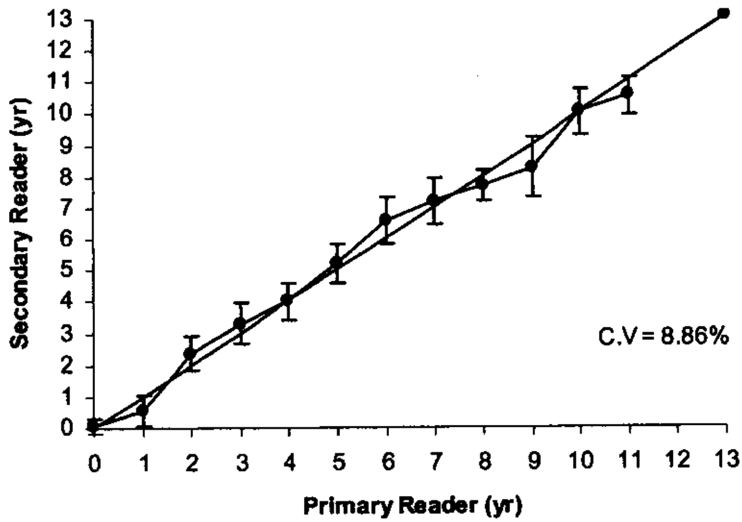

Figure 7. Age bias plot of secondary reader versus the primary reader for sectioned otoliths of *Caranx hippos*. Each error bar represents the 95% confidence interval about the mean age of the secondary reader. The 1:1 equivalence line is also indicated.

Mean observed length-at-age data for whole and sectioned otoliths, Table 1, was used to generate growth parameter estimates, Table 2, and to construct growth models for *C. hippos*, Figure 8 and 9. Back-calculated mean length-at-age Tables 3,4 and 5 for combined sexes, males and females were derived based on the otolith radius (OR)-fish length (FL) regression lg OR = 0.86231g FL-2.3351 (r^2adj = 0.909). These back-calculated mean lengths were also used to generate growth estimates (Table 2) and growth model for *C. hippos* (Figure 10). Growth of *C. hippos* is sexually dimorphic with females attaining a higher asymptotic length than males, however males have a faster growth rate. Growth parameter estimates of females were very similar for observed and back-calculated lengths of whole and sectioned otoliths, Table 2. For males, observed mean length-at-age data for whole and sectioned otoliths were similar, but back-calculated mean lengths of sectioned otoliths gave lower estimates of L_∞ and t_0 and a corresponding higher K value, Table 2. The similarity in growth parameters between whole and sectioned otoliths is probably due to the age groups 10, 11 and 13 not being used to calculate the estimates and the fairly similar mean length at age data for age groups 1 to 7 for both whole and sectioned otoliths. This omission was because of the small sample size for age groups 11 and 13 and the lower than expected mean length at age for Age 10 males, relative to that of Age 9.

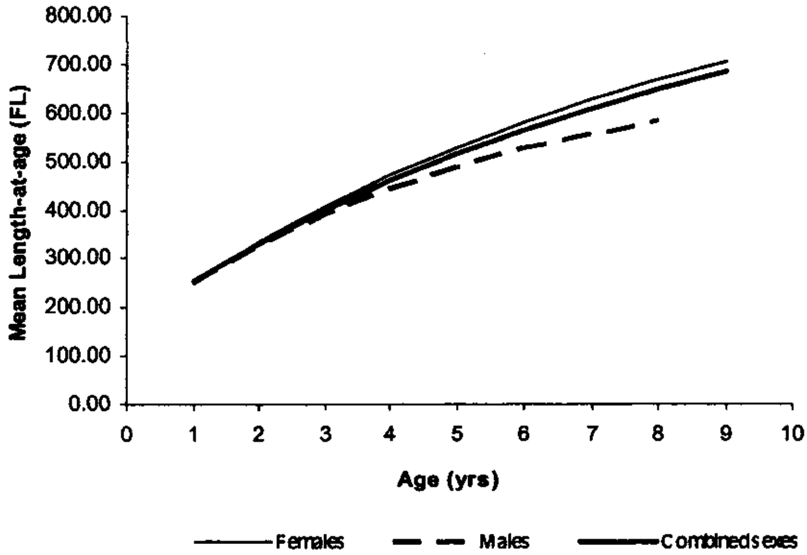

Figure 8. Von Bertalanffy growth model of *Caranx .hippos* from Trinidad based on observed mean length-at-age of whole otoliths

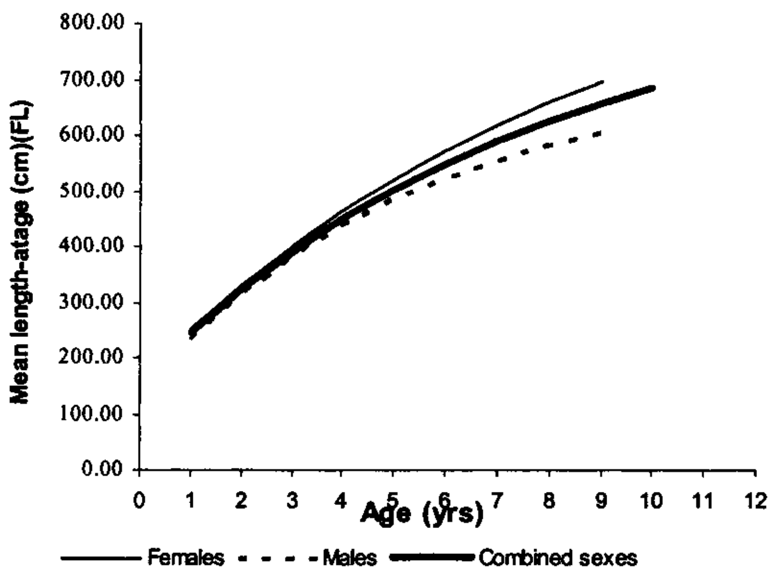

Figure 9. Von Bertalanffy growth model of *Caranx hippos* from Trinidad based on observed mean length-at-age of sectioned otoliths

Table 1. Mean length at age data for whole and sectioned otoliths of *Caranx hippos* from Trinidad. (Standard errors and sample numbers are in parentheses).

	Whole otoliths			Sectioned Otoliths		
Age	Mean Observed Length-at-Age (combined sexes)	Mean Observed Length-at-Age (females)	Mean Observed Length-at-Age (males)	Mean Observed Length-at-Age (combined sexes)	Mean Observed Length-at-Age (females)	Mean Observed Length-at-Age (males)
1	259.2 (4.02;19)	266.5 (5.50;11)	252.4 95.41;5)	253.1 (5.81;23)	261.3 97.65;15)	237.6 (6.76;7)
2	354.3 (21.82;25)	364.4 (33.43;16)	336.2 (13.45;9)	338.5 (8.25;15)	349.1 (8.99;9)	322.7 (14.08;6)
3	367.7 (14.09;22)	370.9 (18.26;12)	363.8 (22.96;10)	349.4 (11.30;5)	355.7 (17.36;3)	340.0 (15.0;2)
4	421.4 (12.48;24)	407.3 (23.91;8)	428.5 (14.66;16)	456.2 (9.66;17)	470.9 (11.51;10)	435.1 (13.98;7)
5	532.1 (14.62;35)	546.7 (18.41;21)	510.3 (23.52;14)	487.5 (11.84;24)	492.3 (8.83;6)	485.9 (15.63;18)
6	551.1 (14.73;33)	586.6 (17.58;14)	526.1 (20.47;19)	579.3 (18.82;15)	605.1 (23.56;9)	540.7 (25.46;6)
7	620.7 (20.08;27)	667.2 (26.11;11)	588.8 (26.46;16)	605.7 (17.84;17)	607.5 (22.79;8)	604.0 (28.25;9)
8	659.6 (69.76;5)	818.0 (30.00;2)	554.0 (44.51;3)	604.2 37.67;13)	672.3 (58.77;6)	545.7 (39.64;7)
9	676.0 (33.60;3)	676.0 (33.60;3)		572.6 (47.74;8)	696.0 (54.0;2)	531.5 (52.02;6)
10				571.6 (63.72;5)	717.5 (70.5;2)	474.3 (7.31;3)
11				639.0 (93.64;3)		639.0 (93.64;3)
12						
13				714.0 (;1)		714.0 (;1)

Table 2. Summary of growth parameter estimates for *Caranx hippos* from Trinidad from this study compared with Palko (1984). (Standard errors are in parentheses). (Growth parameters for Palko (1984) regenerated by the

Category	Type of Hard-Part	L_∞(mm)	K (yr^{-1})	t_0 (yr)	r^2 (adj)	n
Observed Length-at-age (combined sexes) (ages 1-10)	Whole otolith	1014.0 (26.90)	0.104 (0.054)	-1.776 (0.822)	0.900	193
Observed Length-at-age (females (ages 1-7)	Whole otolith	1000.80 (75.66)	0.116 (0.163)	-1.480 (1.700)	0.862	98
Observed Length-at-age (males (ages 1-8)	Whole otolith	719.08 (13.36)	0.177 (0.089)	-1.395 (0.863)	0.940	92
Observed Length-at-age (combined sexes) (ages 1-10)	Sectioned otolith	908.47 (299.50)	0.121 (0.081)	-1.625 (1.000)	0.947	146
Observed Length-at-age (females (ages 1-9)	Sectioned otolith	1044.0 (303.28)	0.103 (0.058)	-1.673 ((0.858)	0.961	70
Observed Length-at-age (males (ages 1-9)	Sectioned otolith	709.42 (174.15)	0.188 (1.090)	-1.091 (1.045)	0.890	75
Back-calculated length-at-age (combined sexes) (ages 1-13)	Sectioned otolith	972.52 (16.50)	0.097 (0.039)	-2.553 (0.163)	0.949	146
Back-calculated length-at-age (females) (ages 1-9)	Sectioned otolith	1058.30 (177.77)	0.103 (0.035)	-1.934 (0.553)	0.985	63
Back-calculated length-at-age (males) (ages 1-9)	Sectioned otolith	621.10 (38.92)	0.276 (0.074)	-0.986 (0.530)	0.951	82
Observed length at age (combined sexes) Palko (1984)	Sectioned otoliths	856.7 (32.22)	0.446 (0.097)	0.365 (0.265)	0.899	59
Back-calculated length at age (combined sexes) Palko (1984)	Sectioned otoliths	844.92 (11.19)	0.299 (0.014)	-0.041 (0.132)	0.992	59

Age length keys were developed to determine the age structure of the commercial catch of *C. hippos* in Trinidad. Although large individuals were collected from the gamefish tournaments, the artisanal commercial fishery also caught similar and even larger individuals and therefore all the samples in this study should be reflective of the commercial catch. Of the population, the age range of YOY - 5 years, comprise 84 % and 73 % respectively for females and males, the YOY composition are 36 % and 28 % respectively for female and males. Age groups 1 - 3, 4 - 5, and 6 - 10 of the females comprise 32 %, 15 % and 2 % respectively. Age groups 1 - 3, 4 - 5, 6 - 10 and 11 - 13 of the males comprise 22 %, 23 %, 24 % and 3 %, respectively.

DISCUSSION

Sagittal otoliths of *C. hippos* have consistent opaque and alternating translucent bands, with the sectioned otolith generally having more annuli when compared to its whole equivalent. Palko (1984) also evaluated the hard-parts and found that the otolith and the vertebra were better than dorsal and anal rays and scales. Palko (1984) used sectioned otoliths to age samples greater than 200 mm indicating it as a preferred choice. The sectioned otolith in this study reveal more annuli than their respective whole otolith also confirming their use as a choice hard-part for age determination. Although validating the periodicity of formation of these annuli through edge type analysis was inconclusive, the focus-to-annulus measurements on the sectioned otoliths showed a single mode for each ring or band and a specific annulus location on the otolith.

L_∞ values for females for all the studies are very similar, Table 2, however the K values and t_0 values are different among the several categories of analysis, Table 2. Unlike Palko (1984), this study revealed a sexually dimorphic growth pattern of *C. hippos* with the females attaining a larger size, but the males having a faster growth rate, Table 2. Growth parameter estimates for Palko (1984) were derived from the available observed and back-calculated mean lengths at age by the authors of this study using FiSAT. Although the L_∞ values may be similar and the mean observed length at age 1 of 266 mm by Palko (1984) comparable to this study (Table 2), the subsequent mean length at age for ages 2, 3, 4,5, 6, 7, 8, 9, 11, and 12 are 283 mm, 655 mm, 716 mm, 774 mm, 792 mm, 822 mm, 845 mm, 827 mm, 839 mm and 823 mm respectively are very different and much higher than those of this study from Ages 3 - 12, Table 2. The vast difference in the mean length at age data implies a different annulus interpretation on the sectioned otolith to the one used by this study, which this study has to some extent tried to validate based on the focus to annulus measurements. It is difficult to compare these two studies for the same reasons noted by Johnson et al. (1995) for the lane snapper, *Lutjanus synagris* because of factors such as the sample size, size of the largest fish, separation of lack of separation of sexes, and different methods of back-calculation.

The age length key for *C. hippos* in this study shows a heavy exploitation of young fish. The fishery of *C. hippos* is unique in Trinidad in that the smaller fish are preferred over the large individuals to the extent that the price per lb of large individuals (>700 mm) when these samples were bought was lower than the of smaller fish. This preference is due to the taste of the flesh because of the relatively higher volume of blood and bleeding of these individuals is usually recommended. The growth parameter estimates provided in this study is the first for Trinidad as well as the Caribbean and should provide a basis upon which a resource assessment can be done for this commercially and recreationally important species.

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