Age and Growth of Wenchman (*Pristipomoides aquilonaris)* from the Northern Gulf of Mexico

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ABSTRACT

Pristipomoides aquilonaris (wenchman, n = 115) were collected off Louisiana and Florida during October - November 2007 along a depth range of 77 - 192 m. Fish were weighed and measured to the nearest 0.001 kg and 1.0 mm, respectively. Both sagittal otoliths were removed and right otoliths were sectioned using a low speed saw with a diamond wafering blade. Readers used otolith growth increment measurements on various whole and sectioned otoliths from fish of differing sizes to determine average placement of core and growth increments. Each specimen was aged (using increments), and agreement between 2 readers was calculated using: average percent error (3.98%), coefficient of variation (5.62%), index of precision (3.98%), and percent agreement ± 1 band (83.5%) and ± 2 bands (97.4%). Linear and nonlinear regressions were fit to meristic and depth data. Age frequencies demonstrated a large group of individuals with 1 or 2 otolith growth increments. Length frequencies showed more than a third of the collection was 150 - 174 mm fork length (FL). Size-at-age with fork length and whole weight and the von Bertalanffy growth curve all showed similar growth patterns and asymptotic trends. We conclude that more wenchman of various sizes and locations should be collected monthly to improve accuracy in the relationship between age and growth.

KEY WORDS: Wenchman (*Pristipomoides aquilonaris*), age, growth

Edad y Crecimiento del Voraz *Pristipomoides aquilonaris* del Norte del Golfo de México

Se colectaron especímenes del voraz, *Pristipomoides aquilonaris* (n = 115), de octubre a noviembre del 2007 en las costas de Louisiana y Florida a lo largo de un gradiente de profundidad de 77 a 192 m. Se extrajeron ambos otolitos y los otolitos derechos se seccionaron utilizando una sierra de baja velocidad con una hoja de diamante. Los lectores utilizaron mediciones del incremento en crecimiento de diversos otolitos enteros y seccionados de peces de distintos tamaños para determinar la ubicación media del centro y los incrementos de crecimiento. Se determinó la edad de cada espécimen (utilizando los incrementos) y se calculó el acuerdo entre 2 lectores utilizando: el error porcentual medio (3,98%), el coeficiente de variación (5,62%), el índice de precisión (3,98%) y el porcentaje de acuerdo de ± 1 (83,5%) y ± 2 bandas (97,4%). Se ajustaron regresiones lineales y no lineales a datos merísticos y de profundidad. Las frecuencias de edades demostraron la existencia de un grupo grande de individuos con 1 y 2 incrementos de crecimiento. Las frecuencias de longitudes mostraron que la mayoría (37%) de los individuos en la muestra medían entre 150 y 174 mm de longitud furcal (FL). El tamaño a cada edad con la longitud furcal y el peso entero, así como la función de crecimiento de von Bertalanffy, mostraron patrones de crecimiento y tendencias asintóticas similares. Se concluyó que habrá que colectar más especímenes de distintos tamaños y distintas localidades mensualmente para mejorar la exactitud de la relación entre la edad y el crecimiento.

PALABRAS CLAVES: Voraz (*Pristipomoides aquilonaris*), edad, crecimiento

Age et Croissance de *Pristipomoides aquilonaris* du Nord du Golfe de Mexique

Pristipomoides aquilonaris (wenchman, n = 115) ont été collectés d'octobre à novembre du 2007 en Louisiane et Floride à une profondeur d'entre 77 et 192 m. On a extrait les deux otolithes et les otolithes droits ont été sectionnés à l'aide d'une scie de basse vitesse avec une lame de diamant. Les lecteurs ont utilisé des mesures d'incrément de croissance de plusieurs otolithes entiers et secctionés de poissons de tailles différentes pour déterminer le placement moyen des incréments du centre et des incréments de croissance. On a determiné l'âge de chaque échantillon (en utilisant les incréments) et on a calculé l'accord entre 2 lecteurs en utilisant: l'erreur moyenne en pourcentage (3.98%), le coefficient de variation (5.62%), l'indice de précision (3.98%), et le pourcentage d'accord de ± 1 (83.5%) et ± 2 bandes (97.4%). Des régressions linéaires et non linéaires ont été ajustées à des données meristiques et de profondeur. Les fréquences d'âges ont démontré l'existence d'un grand groupe d'individus avec 1 et 2 incréments de croissance. Les fréquences de longueurs ont montré que la majorité (37%) des échantillons mesuraient entre 150 et 174 mm de longueur furcale (FL). La taille à chaque âge avec la longueur furcale et le poids entier, ainsi que la courbe de croissance de von Bertalanffy, ont tous montré des patrons de croissance et des tendances asymptotiques semblables. On a conclu qu'il faudra collecter plus d'échantillons de wenchman de plusieurs tailles et différentes localités mensuellement pour améliorer l'exactitude de la relation entre l'âge et la croissance.

MOTS CLÉS: Colas vorace (*Pristipomoides aquilonaris)*, âge, croissance

INTRODUCTION

Wenchman, *Pristipomoides aquilonaris,* is a tropical, deep water fish in the Lutjanidae (snapper) family. It is also known as *Anthias aquilonaris* (Goode and Bean 1896). There are no published references with information pertaining to its life history, reproductive season, habitat, or growth rates. More readily available are lengths plus quantity, location, and depths of catch (Goode and Bean 1896, Anderson 1972, Roe 1976, Stott *et al.* 1980, 1981, Darcy and Gutherz 1984, Allen 1985, Grizzle 1986, Robins and Ray 1986, Cuellar *et al.* 1996, Brooks *et al.* 2004). Its distribution lies from North Carolina throughout the Gulf of Mexico and south to Brazil at depths of 19 to 378 m (Roe 1976, Allen 1985, Robins and Ray 1986). Maximum reported sizes are 220 mm fork length (Cuellar *et al.* 1996) and 203 mm standard length in US waters (Grizzle 1986).

Typically wenchman is not harvested commercially, although it may be eaten as a fresh or frozen filet. Seafood distributors offer wenchman (otherwise known as the golden thread fish) as a small filet (Raffield Fisheries, Port St. Joe, Florida, Pers. communication). The Food and Agriculture Organization of the United Nations indicates it may be used as fish meal (Allen 1985). Percent frequency of catch varies widely in trawling (10.7%, Darcy and Gutherz 1984; 0.4%, Cuellar *et al.* 1996; 15 - 50%, Brooks *et al.* 2004) and in combination of trawling, angling, and spearing (4%, Stott *et al.* 1980; 1%, Stott *et al.* 1981; 16 - 21%, Grizzle 1986). Wenchman commercial catch from the Dry Tortugas, Florida (25 m depth) was less than 1% in both 1991 and 1993 (Schmidt *et al.* 1999).

Currently, there are no aging studies available on wenchman, or on the interpretation or validity of otolith growth increments. The purpose of this study was to establish protocols for interpretation of wenchman otoliths and to examine size and age data obtained from individuals caught in the US Gulf of Mexico.

MATERIALS AND METHODS

Collection of Samples

Wenchman (n = 115) were collected in the northern Gulf of Mexico during October – November 2007. Fish were collected aboard the NOAA R/V GORDON GUNTER using a 27.4 m high-opening bottom trawl towed for 30 min after gear settled to the bottom. Each trawl tow was conducted at speeds of 1.5 – 1.8 m/s, ending with an increase to 2.6 m/s at the last 2 – 5 min to force fish into the cod end (NMFS 2002). The depth per tow did not vary more than 9 m from start to finish. An average depth per tow was used for further analysis. Fish were identified, selected randomly, and frozen for further study.

Otolith Removal and Preparation

After thoroughly thawing, each whole fish was weighed to the nearest 0.001 kg. Wenchman were measured to the nearest 1.0 mm, fork length (FL) and total length (TL), and both sagittal otoliths were removed, cleaned, and stored in a vial in a labeled envelope. Both otoliths were weighed to the nearest 0.1 mg. Correlation between right and left otolith weights was examined to determine the interchangeability of otoliths in case one of the pair was damaged, lost, or unreadable.

Otolith Interpretation

A dissection microscope and a color digital camera were used for initial observations and otolith measurements (using Image Tool 3.0). Otoliths from 4 fish smaller than those in our collection (50 – 140 mm FL) were provided by K. Johnson (NOAA Fisheries Service, Pascagoula, Mississippi). Whole otoliths were viewed under reflected light using a dissection microscope to determine the completion of the core and first increment. Horizontal and vertical measurements were taken for comparison to this study's collection of whole otoliths (Figure 1). Otolith growth increments were recorded on whole and sectioned otoliths, from fish of varying sizes (119 – 237 mm FL). Placement of the core and the first annulus were determined by an experienced reader using otolith growth incremental distances consisting of: vertical diameter through the core, core to the ventral axis, core to the ventral sulcus, and core to the first increment on the ventral axis for sectioned otoliths (measured at 20x or 25x; Figure 2). Using these measurements, the reader assigned each fish a number of visible increments and used this guide to

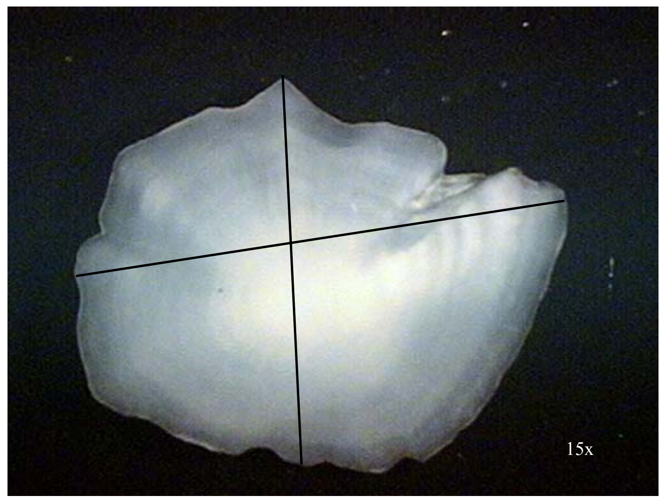

Figure 1. Whole otolith with vertical and horizontal measurements from a wenchman (165 mm FL).

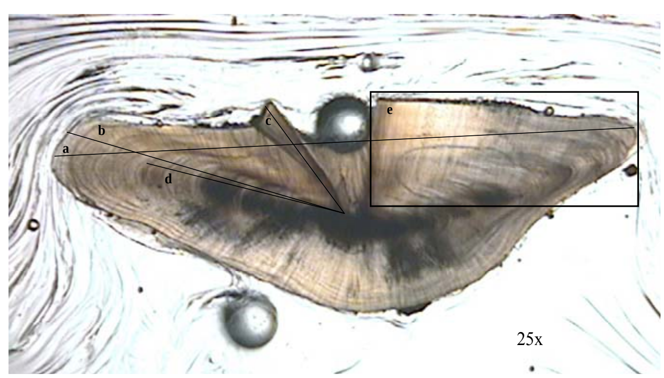

Figure 2. Sectioned otolith of a wenchman (185 mm FL). The following measurements were taken: a) vertical diameter through the core, and core to b) ventral side, c) ventral sulcus, d) end of first increment, and e) clearest viewing area for otolith interpretation.

age the otoliths with relative confidence.

Otolith Sectioning

Otoliths were not easily viewed as a whole structure in fish larger than 160 mm FL, so otoliths were sectioned. Preparation and sectioning procedures were slightly modified from those of VanderKooy and Guindon-Tisdel (2003). A low speed saw with diamond wafering blades was used. Each otolith was placed, sulcus acusticus side down, in a mold containing an epoxy. After otoliths cured 12+ hours, each core was identified and sectioning began 0.6 mm anterior to the core. Three transverse sections were made, resulting in 0.6 mm thick sections, to ensure the core was contained in at least one of these sections. The sections were then lightly sanded, polished, and mounted on a slide using a clear sealant for viewing.

Interpretation of Increments

Throughout this study, age refers to the number of increments, or opaque zones, and aging will refer to the counting of increments. The most consistent area to count increments was along the sulcus acusticus, on the dorsal side (Figure 2e). One increment was considered complete if the increment could be followed on both (ventral and dorsal) sides of the sulcus acusticus. Because it was assumed that wenchman spawned in the spring to early summer and since these fish were caught in the fall, an increment counted at the edge of an otolith was counted as one complete increment.

Reading Agreement

A reader conducted three blind readings, eliminating the first read as a trial event. The collection and fish numbers were the only identifiable information used in the readings. Given that the first reading was a trial, the second and third readings were used in the reading agreement analysis. Average percent error per fish, coefficient of variation per fish, index of precision, overall percent agreement between readings, and percent agreement ± 1 or 2 bands were calculated (Campana 2001). The formula used for average percent error (APE_j) per fish is as follows:

$$APE_j = 100 * (1/R) * (|X_{ij} - X_j| / X_j)$$

Where:
R = number of readings,
X_{ij} = the ith age determination of the jth fish,
X_j = the mean age estimate of the jth fish.
When each fish's APE is averaged, it is known as the index of average percent error.

The formula used for the coefficient of variation (CV) is as follows:

$$CV_j = 100 * \sqrt{[(X_{ij} - X_j)^2 / (R-1)]} / X_j$$

Where:
CV_j = the jth fish's precision estimate,

The index of precision (D_j) is as follows:

$$D_j = (CV_j)/\sqrt{R}$$

Data Analysis

All data were analyzed using Microsoft Excel 2003. Age and length data were used to calculate the age frequency and length frequency of the collection and were combined to calculate the mean size-at-age, along with mean weight-at-age. Meristic regressions were also calculated for length, age, weight, and otolith weight data. These regressions and the respective R^2 values were used to determine if the conversion could be used with confidence to obtain meristic information. In addition, the relationships between age or length and depth of capture were analyzed.

Microsoft Excel 2003 Solver was used to calculate the von Bertalanffy growth curve and its associated indices (Haddon 2001):

$$L_T = L_\infty * \{1 - e^{[-K * (t_i - t_o)]}\}$$

Where:
L_T = fork length at age T,
L_∞ = asymptotic fork length,
K = growth rate coefficient,
t_i = number of increments,
t_o = hypothetical age at which species has zero length.

A geographical information system (GIS) map was produced to spatially plot the sampling site at which each fish was captured. The map was produced using ESRI ArcMap 9.2. There were several layers represented in the map, including depth at varying increments, latitude, longitude, and station locations.

RESULTS AND DISCUSSION

Collection of Samples

We collected 115 wenchman (119 – 237 mm FL) in the northern Gulf of Mexico. Numbers of fish ranged from 1 - 9 fish per station. Stations ranged as far west as Houma, Louisiana and followed the Gulf coast of Florida down to Cape Coral, Florida (Figure 3). Collection depth ranged 77 - 192 m (mean depth ± standard deviation; 135 ± 29 m).

Otolith Interpretation

Right and left otolith weights were closely correlated (R^2 = 0.998; Table 1), providing confidence when selecting either right or left otolith if one was damaged, lost, or if data were missing. In this study, we used the right otolith and its weight for methods and calculations.

Examination of whole and sectioned otoliths indicated that the core should be laid down by 100 mm FL. A group of sectioned otoliths from this study's collection were selected from a range of the smallest fish (119 mm FL) up to the largest fish (237 mm FL) by 10 mm increments. Mean distances from the core to the end of each growth increment for fish 119 – 237 mm FL were used to verify

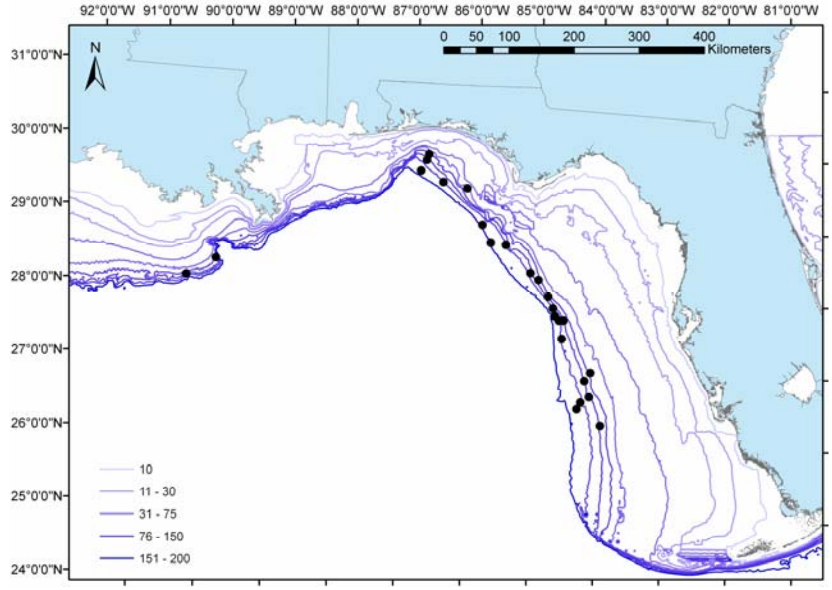

Figure 3. Capture stations of wenchman (n = 115) from the northern Gulf of Mexico (ESRI ArcMap 9.2).

Table 1. Meristic conversions for wenchman. Total length = TL, fork length = FL, whole weight = W. wt., weight = wt., right = R, left = L, otolith = oto.

Conversion and Units	Equation	n	R^2	Data Ranges
FL (mm) to TL (mm)	TL = 0.848*FL - 0.425	114	0.991	FL (mm): 119 - 237
				TL (mm): 135 - 276
FL (mm) to W.wt. (kg)	W. wt.= $3x10^{-8}$*($FL^{2.913}$)	115	0.961	FL (mm): 119 - 237
				W.wt. (kg): 0.033 - 0.265
R to L oto. weight (g)	L = 0.989*R + 0.0021	110	0.998	R (g): 0.056 - 0.473
				L (g): 0.056 - 0.454
FL (mm) to R. oto. wt. (g)	R. oto. wt. = $5x10^{-8}$*($FL^{2.898)}$	115	0.879	FL (mm): 119 - 237
				R. oto. wt. (g): 0.056 - 0.473
W. wt. (kg) to R. oto. wt. (g)	R. oto. wt. = 1.387* ($W.wt.^{0.958}$)	115	0.847	W. wt. (kg): 0.033 - 0.265
				R. oto. wt. (g): 0.056 - 0.473
Age (# increments) to R. oto. wt. (g)	R. oto. wt. = 0.110* ($Age^{0.490}$)	115	0.609	Age (#increments): 1 - 14
				R. oto. wt. (g): 0.056 - 0.473

Table 2. Measurements (mean ± std. dev.) from the core to each growth increment of wenchman sectioned otoliths.

Increment	1	2	3	4	5	6	7	8
sample size	n = 11	n = 6	n = 6	n = 5	n = 5	n = 4	n = 3	n = 3
Mean (mm)	2.87	3.30	3.74	4.11	4.45	4.68	4.95	5.09
Std. dev.	0.38	0.40	0.42	0.45	0.46	0.48	0.60	0.72

the placement of growth increments (Table 2).

Reading comparison was completed between the second and third readings. Reader comparison bias plots showed very little variation between readings. The APE index between the two readings was 3.98%. Campana (2001) indicates that an APE of 5% or below is acceptable. Coefficient of variation was 5.62%. Index of precision was 3.98% because it is identical to APE when there are two readers (Campana 2001). The percent agreement within ± 1 increment between readings was 83.5% and within ± 2 increments was 97.4%. The difference between 1 or 2 increments was largely due to the difficulty in identifying the first and the last increment (Figure 2).

Data Analysis

Meristic conversions were calculated to make predicted measurements (Table 1). Linear regressions were fit to meristic data and resulted in reasonable R^2 values (> 0.991). Nonlinear regressions also resulted in reasonable relationships (R^2 > 0.847). The relationship between age (number of increments) and otolith weight was not as clear (R^2 = 0.609), possibly due to variation in interpretation of otolith growth increments (Figure 4). Linear regressions calculated for age (R^2 = 0.026) or FL (R^2 = 0.019) versus depth resulted in no particular patterns. This may indicate no size-based groups of individuals at specific depths, although the individuals were selected randomly at each site and most sites were grouped along the west coast of Florida.

Age and length frequencies were calculated to seek trends in sizes at each age. The majority of fish collected were age 1 and 2 (30% and 22%, respectively; Figure 5). Very few older fish were caught (> 8 increments, n = 7). Length frequency showed a large group of individuals at 150 - 174 mm FL, and represented 37% (n = 43) of the collection (Figure 6). The next largest group was 175 - 199 mm FL, which included the mean fork length of 180 mm, comprised 23.5% (n = 27) of the collection. The extremes were 119 mm FL (135 mm TL) and 237 mm FL (276 mm TL). This study collected larger sizes of wenchman than has been presented in the literature (Roe 1976, Allen 1985, Grizzle 1986, Robins and Ray 1986, Cuellar *et al.* 1996).

Mean observed size-at-age comparisons resulted in small deviations around the means of both length and weight for younger fish (Figures 7 and 8). However, larger deviations were present at older ages (ages 6 and 8). This might have resulted from difficulty in distinguishing increments from each other as otoliths grew in different proportions (Figure 9).

The von Bertalanffy growth curve was fitted to observed FL and age (Figure 10). Least squares nonlinear regression was used to predict length of a fish as a function of its age. This is a common practice in predicting age and length of fishes (Haddon 2001), but it has its assumptions as well. Haddon (2001) notes that it is typical for many data sets to have many average-aged and -sized fish, leaving the estimated lengths for older and younger fish at a bias. The von Bertalanffy growth curve resulted in a realistic asymptotic length (L_∞ = 240 mm FL, max. observed = 237 mm FL). The growth coefficient was close to 0.20 (K = 0.18), but t_o was slightly inflated (t_o = - 4.75). Older ages tend to give an asymptotic pattern as fork length increases in both observed and estimated data points approaching L_∞. This is similar to the observed trend in the

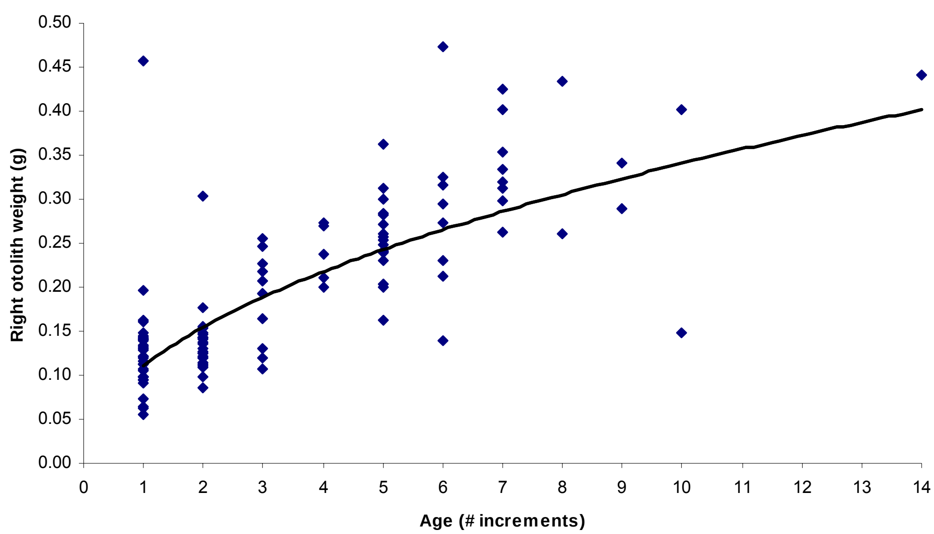

Figure 4. Age and otolith weight regression for wenchman (n = 115). Line is fitted from a non-linear regression.

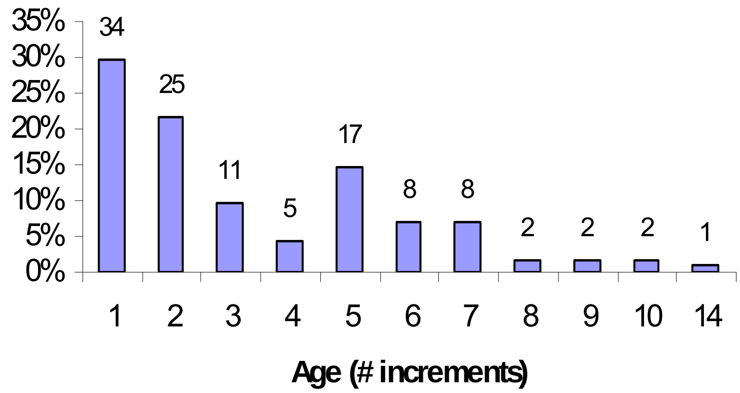

Figure 5. Age frequency of wenchman (n = 115). Sample sizes per age above bars.

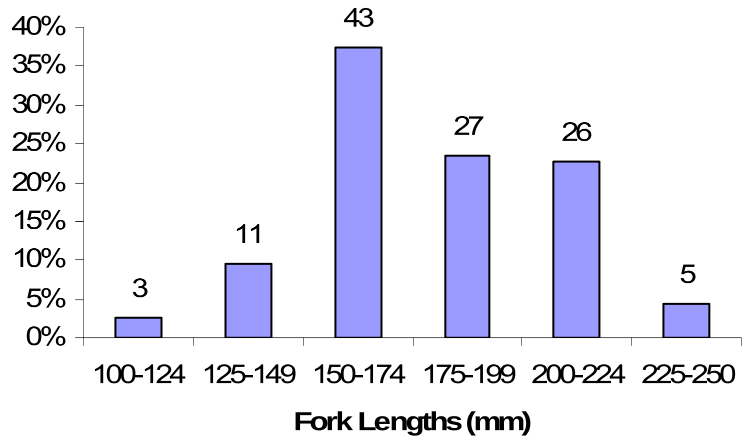

Figure 6. Length frequency of wenchman (n = 115). Sample sizes per size bin above bars.

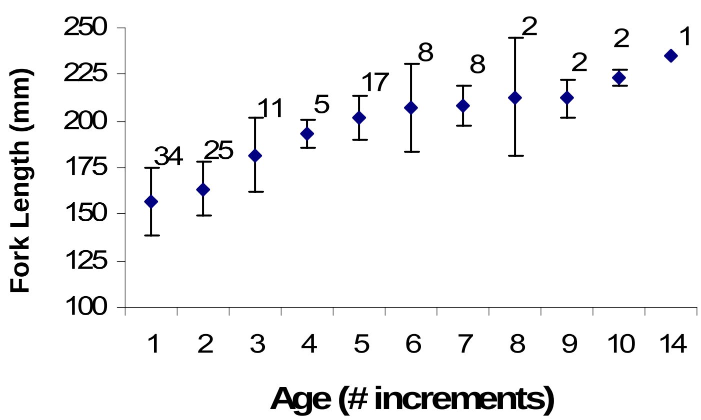

Figure 7. Size-at-age (mean ± std. dev.) of wenchman (n = 115). Sample sizes above error bars.

relationship between age and whole weight (Figure 8).

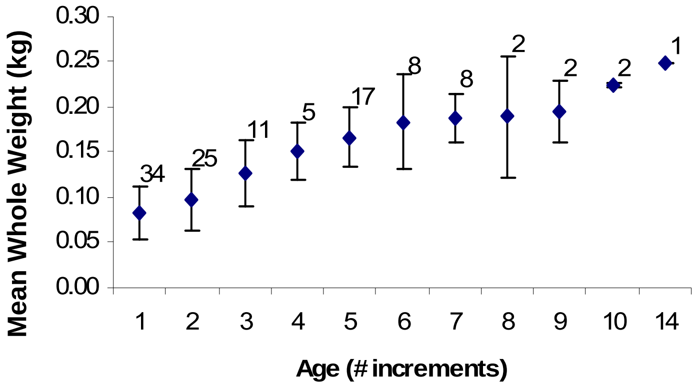

Figure 8. Weight-at-age (mean ± std. dev.) of wenchman (n = 115). Sample sizes above error bars.

Figure 9. Comparison of two otoliths of wenchman: a) 145 mm FL fish with 1 growth increment, b) 224 mm FL fish with 7 growth increments. Increments marked by asterisks.

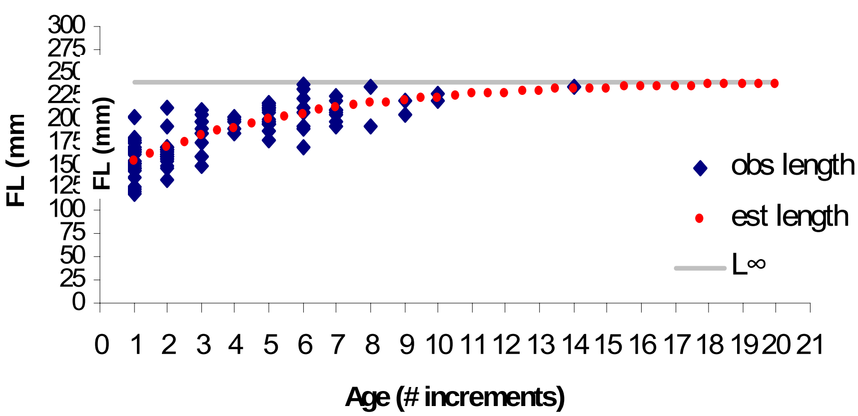

Figure 10. von Bertalanffy growth curve (dotted line) fit to observed fork lengths and estimated ages (diamonds) of wenchman caught by deep water trawl in the Gulf of Mexico (n = 115). Line of reference is the asymptotic length (L_∞).

FUTURE WORK AND CONCLUSION

Study of wenchman in the future will benefit from more individuals collected at varying sizes, seasons or months, locations, and in larger quantity. Additional research to determine the reproductive season of wenchman would assist in determining when growth increments were deposited. Furthermore, monthly samples would also assist in validating if each increment is annually deposited. Potential methods for validating annual increments include tag and recapture, mark-recapture of chemically tagged fish, captive rearing from hatch, daily increment analysis between annuli, and back-calculation (Jearld 1983, Stewart *et al.* 1995, Campana 2001).

Although wenchman is not as commercially important as other snapper species, it is evident there is a need for understanding the age and growth of tropical, deep water species (Azemia *et al.* 2000, Morales-Nin & Panfili 2005). Azemia *et al.* (2000) concluded that a fish of the same genus, *P. filamentosus,* found in relatively deep water (more than 30 m) may be buffered against environmental change and thus otoliths may be unsuitable for differentiating growth increments due to abiotic changes not associated to a time scale. However, Morales-Nin and Panfili (2005) noted that tropical and deep water areas may not be aseasonal, but rather the seasons are represented by periods of reproduction and growth, fueled by food supply, or possibly by detectable temperature variations by temperature-sensitive species. When the reproductive season and life history have been established for the wenchman, more conclusions can be made for other similar commercially important species.

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