A Comparison of Age Estimates from Sagittal Otoliths and the First Dorsal Spine for Cobia (*Rachycentron canadum*) from the Northcentral Gulf of Mexico

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ABSTRACT

Cobia, *Rachycentron canadum*, are migratory, coastal pelagic fish that are distributed worldwide in tropical and subtropical seas, except for the eastern Pacific, and are abundant in the Gulf of Mexico. Previous research established that cobia from the northern Gulf of Mexico could be aged using sectioned sagittal otoliths, however the collection of sagittae from cobia typically requires removal of the entire head for subsequent otolith extraction and sectioning in the laboratory, generally a difficult and time-consuming process. In this study, first dorsal spines and whole sagittal otoliths were assessed as ageing structures for cobia collected from the northcentral Gulf recreational fishery. The accuracy of age estimates, based on counts of opaque bands on whole sagitta and translucent bands on dorsal spine sections, was determined by comparison with age data from sectioned sagittae from the same fish. Spine sections exhibited concentric translucent bands for most fish, but outer bands were often closely spaced and difficult to interpret. Vascular erosion of the central core of spines from some large fish obscured the inner (early) growth bands which required their "replacement". Vague bands were typical of many whole otoliths which led to numerous discrepancies in band counts among readers. Agreement among three readers for the number of bands on sectioned otoliths, whole otoliths and sectioned spines was 100 %, 86.1 % and 97.7 %, respectively. Age agreement between sectioned otoliths and sectioned spines (61.9 %) and sectioned otoliths and whole otoliths (61.3 %) was generally not satisfactory for any age category, and some whole otoliths and spines over- and under-estimated ages by as much as two years. Under- and over-estimations of age obtained from whole sagittae and sectioned spines have obvious implications in estimating mortalities for use in fisheries management. Although dorsal spines were far more practical in terms of ease of collection, they do not represent a viable alternative for deriving age estimates for cobia. This study demonstrated that it is essential to section sagittal otoliths from cobia in order to obtain an accurate age.

KEY WORDS: *Rachycentron canadum*, age, otoliths, spines

Comparacion de la Edad Estimada con Otolitos Sagitales y la Primera Espina Dorsal en Cobia (*Rachycentron canadum*) en el Norte del Golfo de Mejico

Cobia, *Rachycentron canadum*, es un pez costero pelágico y migratorio distribuido en los mares tropicales y subtropicales de todo el mundo, con excepción del Pacífico oriental. Previas investigaciónes establecieron que la edad de la cobia capturada recreacionalmente en el norte del Golfo de Mejico podría ser estimada con exactitud utilizando otolitos sagitales seccionados. La colección de sagittae en la cobia cosechada por los pescadores típicamente requiere la remoción de la cabeza entera para extraer el otolito y luego su disección en el laboratorio, a menudo un proceso difícil que consume mucho tiempo. Realizamos una comparación entre las edades estimadas utilizando los otolitos sagitales enteros y seccionados y las primeras espinas dorsales seccionadas. Los sagittae enteros presentaron las zonas del crecimiento asumidas como acontecimientos anuales, y las secciones de la espina dorsal revelaron una sucesión de bandas opacas y translúcidas alternas, aunque no validas como piezas anuales, fueron utilizadas en la valoracion de la edad. En algunos peces grandes, la erosión vascular de la base central de las espinas dorsales obscureció las bandas (tempranas) internas de crecimiento lo que requirio su reemplazo estadístico. La exactitud de la edad estimada con las lecturas de la sagitta entera y de la espina dorsal seccionada fue comprobada comparando esos datos con los obtenidos con los sagittae seccionados de los mismos peces. Aunque es más difícil colectar, los sagittae proporcionan una información más detallada de la edad, sin embargo, las espinas dorsales son más prácticas en términos de la facilidad de colección y pueden representar una alternativa para derivar las estimaciones de edad para la cobia.

PALABRAS CLAVES: Cobia, *Rachycentron canadum*, edad estimada, otolitos

INTRODUCTION

Cobia, *Rachycentron canadum*, is a migratory, coastal pelagic fish that occurs worldwide in tropical and subtropical seas, except for the eastern Pacific, and is most common in the west-central Atlantic region along the southern U.S. coast, including the Gulf of Mexico (Gulf) (Shaffer and Nakamura 1989). Cobia are rapid-growing fish with moderate life spans, having been aged to eleven years for females and nine years for males in the northern Gulf (Franks et al. 1999). This species appears to follow an annual migratory pattern in Gulf waters, typically over-wintering in south Florida followed by a northward migration along western Florida in early spring (Hendon and Franks 1999). From spring through fall, cobia range off northwest Florida to southwest Louisiana, returning to south Florida waters in late fall. Some fish in the northern Gulf reportedly do not follow this migratory pattern and overwinter in the northern Gulf in depths of 100 to 125 meters deep (Howse et al. 1992).

Cobia is highly sought by anglers in the northern Gulf, where the majority of U. S. cobia recreational landings occur (Shaffer and Nakamura 1989). From 1997 to 2000, recreational landings of cobia from western Florida to Louisiana averaged over 500,000 kg per year (NMFS pers. comm.). Although a commercial fishery for this species also exists in this region, it is minor (85,000 kg per year over the same time period) compared to its recreational counterpart, and no commercial fishery exists in Mississippi where it is illegal to sell cobia caught in state waters or landed in the state (MDMR, 2001). Because of its popularity, cobia is managed in both state and federal waters in the U.S. Gulf. Both the recreational and commercial cobia fisheries are regulated by a 33-inch (837 mm) fork length (FL) minimum size limit and a two fish/person daily bag (possession) limit in federal waters (GMFMC, 2001). Each of the Gulf states has implemented similar restrictions in its state waters.

Because cobia are sought by a wide range of user groups, this fishery in the northern Gulf must be properly monitored to ensure the health of the stock, and data on the age structure of the current population are needed to adequately assess the status of the fishery. Previous research established that cobia from the northern Gulf recreational fishery could be aged using sectioned sagittal otoliths (Franks et al. 1999). The collection of sagittae from cobia typically requires removal of the entire head for subsequent otolith extraction and sectioning in the laboratory, generally a difficult and time-consuming process. As an alternative to this technique, recent studies have successfully utilized dorsal and anal spines to estimate age in several fishery species, including albacore tuna (Gonzalez-Garces and Farina-Perez 1983), little tunny (Cayre and Diouf 1983), gray triggerfish (Bernardes 2002), swordfish (Tserpes and Tsimenides 1995) and wahoo (Franks et al. 2000).

The objective of this research was to assess the first dorsal spine, a more readily-accessible bony part, from cobia as an ageing structure by comparing age estimates from analyses of sectioned first dorsal spines and sectioned sagittal otoliths. In addition, the accuracy of age estimates obtained from whole sagittae were evaluated by comparison with ages from sectioned sagittal otoliths. Although sectioned sagittal otoliths typically represent the ideal ageing structure, dorsal spines are more practical in terms of ease of collection, particularly for researchers conducting fishery-dependent (dock-side) surveys, and may represent an alternative for deriving age estimates for cobia.

MATERIALS AND METHODS

Cobia were obtained from the northern Gulf recreational fishery, primarily during fishing tournaments, from September 1997 to March 2000. Date of capture, fork length (FL, mm) and sex were recorded for each specimen sampled. The head and first dorsal fin spine were removed from each fish, stored on ice and returned to the laboratory for processing.

Laboratory Preparation and Age Determination

Sagittal otoliths were extracted from cobia heads and, along with first dorsal spines, were thoroughly cleaned of excess tissue and air-dried. Whole otoliths and dorsal spines were weighed to the nearest 0.001 g, and dorsal spines were measured from the condyle base to the tip of the spine to the nearest 0.1 mm. The first dorsal spine and one otolith from each fish were embedded in an epoxy resin and sectioned transversely at 0.3 mm with a Beuhler Isomet low-speed saw. Otoliths were sectioned through the core along a transverse, dorsoventral plane, and spines were cut (on average) at 30 % of their length, extending from the condyle base to the tip.

Sectioned spines and sectioned otoliths were viewed under a dissecting microscope (20 - 40x magnification) using transmitted light. Whole otoliths were viewed on a black background with direct light. The authors were familiar with reading opaque bands on sectioned sagittae (Franks et al. 1999), however we carried out an initial training exercise in the reading of whole otoliths and sectioned spines by making counts on a small subsample of those structures and comparing counts with ages from sectioned otoliths. Subsequent readings were carried out "blind", i.e. the readers did not know the size or sex of the cobia. By using marginal-increment analysis, Franks et al. (1999) determined that age in years for cobia sampled from the northern Gulf was equal to the number of opaque bands observed on sectioned sagittal otoliths. For purposes of this research, age derived from sectioned otoliths was considered to be the "actual age" of the fish.

Because it was beyond the scope of this study to validate markings on sectioned spines as true annuli, a "presumed age" was assigned to each dorsal spine by counting the number of distinctive, concentric translucent bands that appeared to encircle most of the spine's circumference. In some instances, particularly for larger fish, vascular erosion of the central core of spines destroyed the inner (early) growth bands which required the readers to estimate ("replace") the number of bands concealed in this region to arrive at a "corrected age". Therefore, using an image analysis system, measurements of the distance from the spine's core to early growth bands (1st, 2nd and 3rd) observed on legible sections from small spines (young fish) provided guidance for estimating the approximate distance of obscured early growth bands from the spine's core on centrally eroded areas of large spines (older fish). Also, visual comparison of sections from larger dorsal spines with those from smaller spines exhibiting obvious early growth bands provided additional guidance for the "replacement" of missing bands. Examination of other dorsal spine sections from the same fish frequently resolved discrepancies. Spine radius (the straight line distance from the estimated core of the spine section to the right margin of the section) was also measured for legible spine sections.

Age estimates using whole otoliths were made by a combination of:

i) Counting the number of translucent bands on the distal side of the rostrum,
ii) Counting the number of "ridges" along the distal ventral portion of the structure, and
iii) Counting the number of "steps" along the sulcal groove (proximal side). Based on the findings of Franks et al. (1999) for sectioned cobia sagittae,

opaque growth zones observed on whole sagittae were assumed to represent annual marks.

Independent readings of the ageing structures were made twice by each author, and when disagreement occurred among readings, a mutual assessment of the ageing structure was conducted. If agreement could then not be reached, questionable structures were disregarded.

Statistical Analyses

The relationship between somatic growth and growth of the first dorsal spine was determined by modeling FL with spine length, spine weight and spine radius for each sex using linear regression analysis. To test for a positive correlation between age and spine growth, actual age was compared to spine length, weight and radius with linear regression. Additionally, mean ranks of age estimates were compared between structures with the Friedman test, a nonparametric equivalent to repeated measures analysis of variance (SPSS 1999), to test for statistical difference and to determine whether mean age estimates were over- or under-estimated in relation to actual age. For all analyses, statistical significance was considered at $p < 0.05$, and tests were performed with SPSS for Windows, 10.1 (SPSS 1999).

RESULTS

Sample Collections and Reader Agreement

The first dorsal spine and sagittal otoliths were collected from 46 fish, ranging in size from 890 to 1,651 mm FL. Whole otoliths were available for 38 of the 46 fish, ranging in size from 890 to 1,270 mm. The first dorsal spine and whole otolith were unreadable for one fish, which was removed from further analyses, yielding a total sample size of 45 for sectioned otoliths and spines and 37 for whole otoliths. Fish used in this study were sampled during spring months (March-May; $n = 22$) and in February ($n = 10$) and September ($n = 13$). Females ($n = 32$) were more abundant than males, by about a 2:1 ratio.

Initial reader agreement on age estimates was 80.4 % for sectioned otoliths, 51.2 % for sectioned spines and 44.4 % for whole otoliths. After mutual assessment by the authors, agreement increased for sectioned otoliths to 100 %, sectioned dorsal spines to 97.7 %, and whole otoliths to 86.1 %. Three sectioned dorsal spines (6.5 %) and two whole otoliths (5.3 %) were deemed unreadable by the authors, and mutual agreement on the number of bands for one sectioned spine and five whole otoliths could not be reached, resulting in a final sample size of 46 sectioned otoliths, 31 whole otoliths and 42 sectioned dorsal spines.

Examples of Ageing Structures

Although all ageing structures considered acceptable by all three readers for deriving age estimates were not of ideal quality, Figures 1, 2 and 3 show examples of the more legible structures (images not shown at same scale). The cross-section

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of a first dorsal spine from an age-2 cobia is shown in Figure 1a. The spine's core region and two translucent bands are identified. Spine sections from small fish such as this were used as a general guide to assist readers in locating (replacing) obscured early growth bands in the core of spines from larger fish, such as that from an age-4, 1,150 mm cobia (Figure 1b). Figure 2 identifies the opaque bands (annuli) on a thin-sectioned sagitta and the translucent bands on a whole sagitta and sectioned dorsal spine from an age-4, 1,150 mm FL female cobia. Band counts agreed among all structures. Figure 3 identifies the bands on a sectioned sagitta and the evident bands on a sectioned dorsal spine from a large cobia (1,651 mm FL). Based on band counts from the sectioned otolith, three inner bands are obscured in the core of the sectioned spine. Although there was complete reader agreement for band counts on each structure in Figure 3 (spine band count = 8; sectioned otolith band count = 9), spine age was under-estimated by one year.

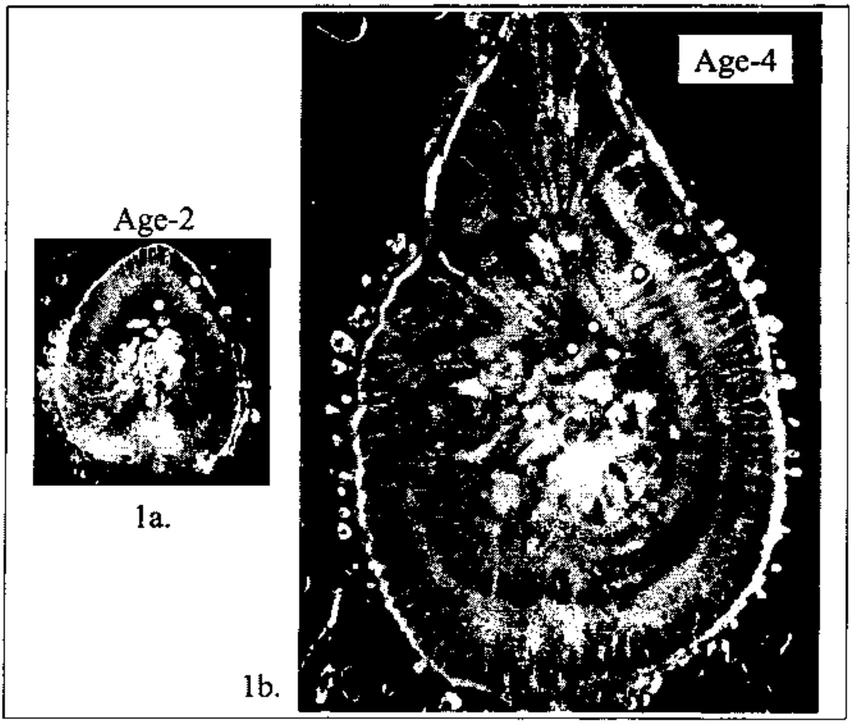

Figure 1. Sectioned first dorsal spine from an age-2 cobia (1a.) used to assist readers in the replacement of obscured inner growth bands in spines from larger fish (e.g., 1b.). o = location of band; C = spine core.

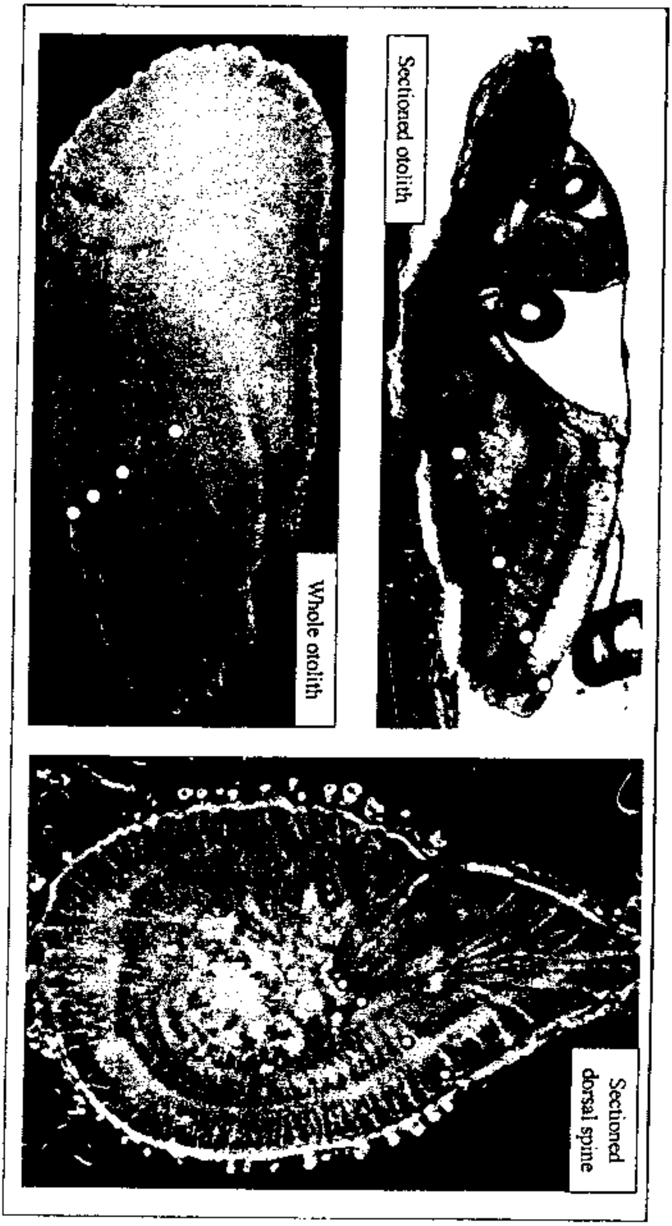

Figure 2. Sectioned sagittal otolith, whole sagittal otolith and sectioned first dorsal spine from an age-4 female cobia (1,150 mm FL). o = location of band; C = spine core.

core.

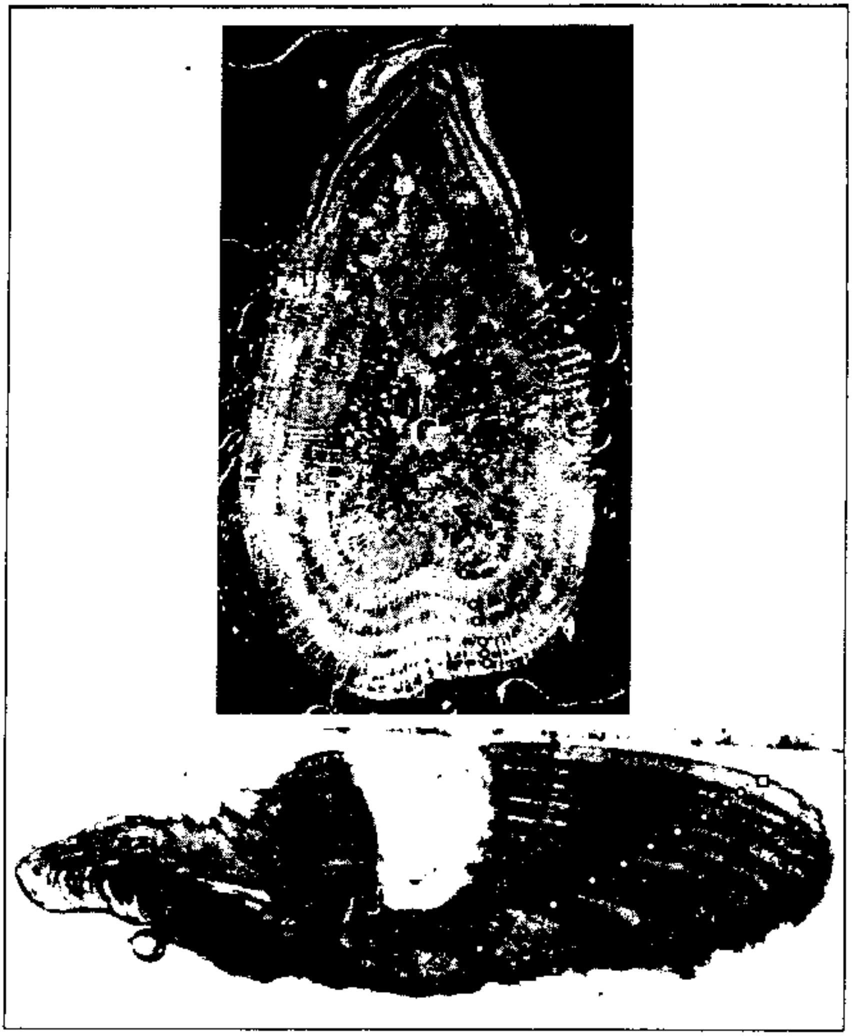

Figure 3. Sectioned first dorsal spine and sectioned otolith from an age-9 cobia (1,651 mm FL). Note: based on sectioned otolith age, three bands are obscured in the core of the sectioned spine. ○ = location of band; □ = otolith margin, not an opaque band; C = spine core.

Growth Relationships and Age Comparisons

Mean FL, spine length, spine weight and spine radius did not differ between the sexes ($p \geq 0.525$), so data for dorsal spines were pooled for regression analyses. Of the six comparisons between age/FL and spine growth, only three were significant, and none showed a strong relationship based on linear regression (Table 1). Only spine weight as a function of FL yielded a moderate association ($r^2 = 0.469$).

Table 1. Regression statistics for first dorsal spine measurements relative to FL and age. Values in parentheses are standard errors. Significant relationships are indicated in bold. "DS" = dorsal spine, and "Age" = actual age.

			$Y = a + bX$			
Y	*X*	n	*a*	*b*	*p*-value	r^2
FL	DS Length	22	836.1 (158.0)	19.9 (11.5)	0.098	0.131
FL	DS Weight	17	909.7 (57.3)	731.6 (200.8)	**0.002**	**0.469**
FL	DS Radius	25	748.4 (104.2)	272.4 (83.0)	**0.003**	**0.319**
DS Length	Age	22	10.6 (1.29)	0.80 (0.33)	**0.024**	**0.229**
DS Weight	Age	17	0.157 (0.083)	0.029 (0.021)	0.191	0.111
DS Radius	Age	25	1.063 (0.160)	0.047 (0.041)	0.266	0.053

The number of translucent bands counted on individual dorsal spines (DS-Age) matched the actual age for 26 of the 42 fish (61.9 %), while age estimates from whole otoliths (WO-Age) matched actual age for 19 of the 31 fish (61.3 %). The accuracy of DS-Age (Figure 4a) and WO-Age (Figure 4b) was relatively high for age-3 and 4 fish, with slightly higher accuracy for DS-Age. Conversely, DS-Age was over-estimated for age-2 fish, while WO-Age tended to over-estimate age for age-2 and 3 fish. Both DS-Age and WO-Age under-estimated age for fish age-5 and older, with the exception of WO-Age for an age-9 fish (Figure 4).

Overall, mean ranks of age estimates did not differ between sectioned otoliths (actual age) and whole otoliths ($n = 31$; $\chi^2 = 0.077$; $p = 0.782$), but age ranks were marginal in significance for the comparison between sectioned otoliths and sectioned dorsal spines ($n = 42$; $\chi^2 = 3.556$; $p = 0.059$). Age estimates from sectioned dorsal spines ($\bar{x}_{rank} = 1.41$), on average, tended to underestimate actual age ($\bar{x}_{rank} = 1.59$).

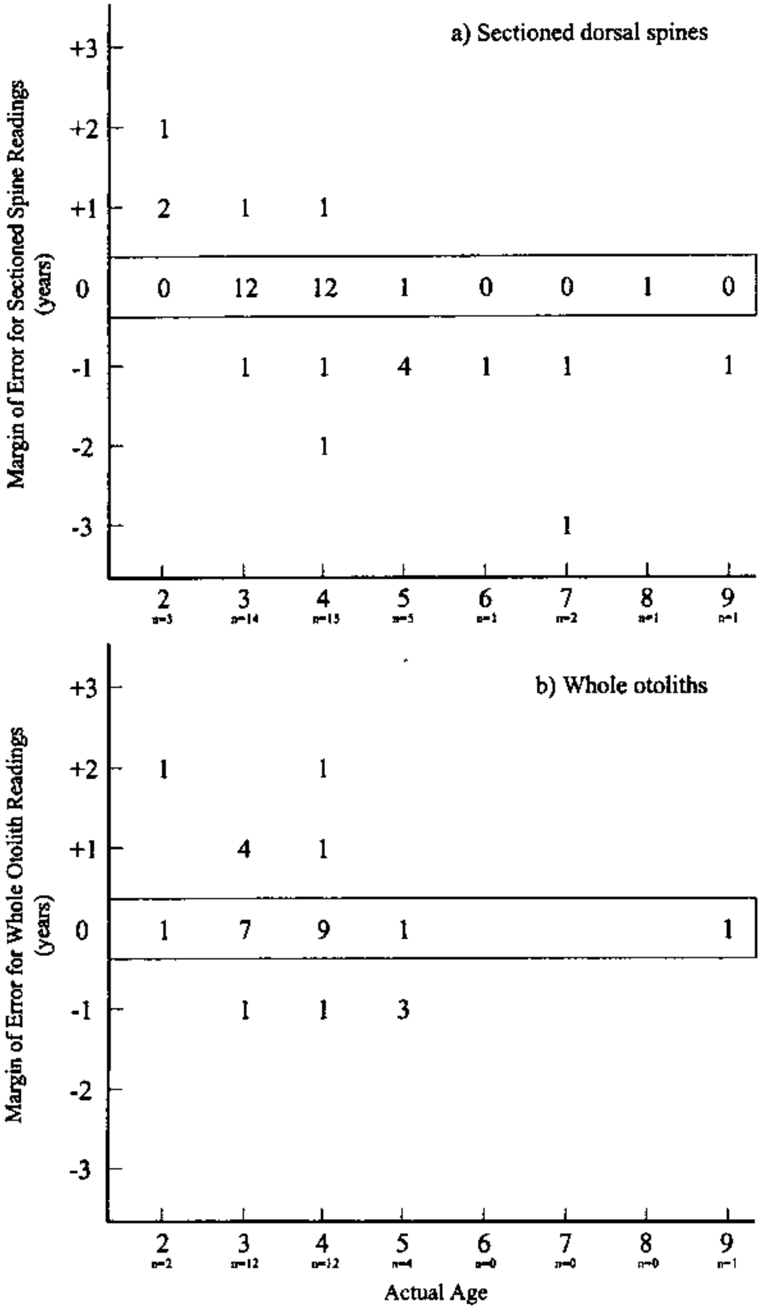

Figure 4. Margin of error for band counts of sectioned first dorsal spines (a) and whole otoliths (b) in relation to actual age (sectioned otoliths) for cobia.

DISCUSSION

In this paper, we examined the merits of sectioned first dorsal spines and whole sagittal otoliths to age cobia, *Rachycentron canadum*, from the northcentral Gulf of Mexico. Our results demonstrated that while sectioned spines and whole otoliths appeared adequate for ageing some fish in our sample, these structures are far less precise for ageing cobia than are sectioned otoliths. Dorsal spines showed a moderately high level of interpretability, however the position of the first, second and often the third transparent band could not be determined consistently, and outer bands were often closely spaced and difficult to discern. Vague, difficult-to-locate bands were typical of many whole otoliths which led to numerous discrepancies in band counts among readers.

Although the linear relationships between age and spine length, FL and spine weight, and FL and spine radius were each significant, there was no strong association between any of these measurements ($r^2 < 0.500$). The lack of a strong association between age and spine length may be attributed to the non-symmetrical growth of some spines. Growth in spine length appears to slow as spine width increases (with increased age), thus reducing the precision of spine length in predicting age in older fish. The weak association between FL and spine weight could be due to increased internal vascularization of the spine as the fish grows, since dissimilar rates of vascularization would cause variations in spine weight among fish of similar size. Based on these factors, spine radius would seemingly be the most accurate measurement for evaluating spine growth, but greater precision relative to the sectioning of spines, i.e. establishing a uniform area on spines for removal of sections, might have produced more positive FL-spine radius and age-spine radius relationships.

Because of the small sample size in this study and the preliminary nature of the research, we did not calculate estimates of precision (repeatability) or an index of average percent error (Beamish and Fournier, 1981) for band counts among readers, but independent readings of each of the three ageing structures were made twice by each reader to arrive at a percent reader agreement. There was total agreement (100 %) among readers on counts of opaque bands on sectioned otoliths, which served as the basis (actual age) for comparison of age estimates derived from whole otoliths and sectioned spines. Although age agreements between sectioned otoliths and sectioned spines (61.9 %) and sectioned otoliths and whole otoliths (61.3 %) were equally unimpressive, there was moderate agreement between sectioned otolith and sectioned spine readings for age-3 and 4 fish, with differences reflected in both slightly lower and higher age estimates. Agreement between sectioned otoliths and whole otoliths was satisfactory only for age-4 fish and the single age-9 fish. Growth bands were not equally clear or consistent on all legible hard parts, and some whole otoliths and sectioned spines over- and under-estimated age by as much as two years.

In summary, we found that whole sagittal otoliths and sectioned first dorsal spines had limited application in estimating the age of cobia, however the caveat regarding small sample size should not be forgotten. Although dorsal spines were

regarding small sample size should not be forgotten. Although dorsal spines were

far more practical in terms of ease of collection, they do not represent a viable alternative for deriving age estimates for cobia, based on the results of this preliminary research. This study demonstrated that it is essential to section sagittal otoliths from cobia in order to obtain an accurate estimate of age. Reasons for this include the readability of sectioned otoliths, the continued growth of otoliths with increasing fish size and age, the increase in the number of annuli with size, and indirect validation of opaque bands as annuli (Franks et al., 1999). Annuli on sectioned sagittae are extremely clear and easy to count, even on those from large fish. In contrast, age estimates from whole otoliths and sectioned spines generally tended to be greater for **smaller** fish (actual ages 2, 3 and 4) and **lesser** for larger fish (actual ages > 4) when compared with sectioned otolith ages. Rocha-Olivares (1998) reported that the magnitude of the difference between whole otolith and sectioned otolith age varies from species to species, but the general trend is an underestimation of ages in older fishes. Similarly, Jones and Wells (1998) found that sectioned dorsal spines from black drum, *Pogonias cromis*, tended to under-estimate age, a trend that increased with increasing fish age, and concluded that sectioned otoliths were the clearest and most precise hard part for interpreting age. The results of our research agree with the findings of those studies. Finally, the under- and over-estimations of age obtained from whole sagittae and sectioned spines have obvious implications in estimating mortalities for use in fisheries management, and further research on the accuracy of these structures is needed before their implementation as age determinants for fishery assessments.

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