

PRELIMINARY STUDY ON REPRODUCING OBSERVED SEX RATIO BY SIZE FOR ATLANTIC SWORDFISH

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SUMMARY

Observed sex ratio as a function of size for the Atlantic swordfish was tried to be reproduced by introducing differential growth and differential natural mortality rates by sex. The observed sex ratio could not be simulated satisfactorily in a varying degree by input of differential growth rate alone or differential natural mortality rate alone as well as both differential growth and natural mortality rates. However, it appears that the differential growth rate is a key element involved in the observed sex ratio of this species.

RESUME

On a tenté de reproduire le sex ratio en fonction de la taille observé pour l'espadon de l'Atlantique en introduisant des taux de croissance et de mortalité naturelle différenciés selon le sexe. Le sex ratio observé n'a pas pu être simulé de façon satisfaisante à un degré variable par l'entrée du seul taux différentiel de croissance, ou du seul taux différentiel de mortalité naturelle, ni par l'entrée des deux taux à la fois. Il semble néanmoins que le taux différentiel de croissance soit un élément clé du sex ratio observé pour cette espèce.

RESUMEN

Se trató de reproducir la proporción de sexos en función de la talla, observada en el pez espada del Atlántico, introduciendo tasas diferenciales de crecimiento y de mortalidad por pesca. La proporción de sexos observada no pudo simularse de forma satisfactoria, en diversos grados, incorporando solo la tasa diferencial de crecimiento o la tasa diferencial de mortalidad por pesca, así como incorporando ambas a la vez. No obstante, parece ser que la tasa diferencial de crecimiento es un elemento clave en la proporción de sexos observada en esta especie.

Introduction

There is a concern over swordfish stock condition in the North Atlantic as the catch remarkably increased in recent few years with the reduction of average size of fish in the catch and decline of possible adult stock although recruitment is apparently on increase. However, it is clear that there are a number of uncertainties as for the basic biological information available to the Atlantic swordfish stock. This makes the interpretation of the results of the stock assessment difficult. Among several doubts on the result of the assessment, unrealistically high fishing mortality coefficient (F) for the possible adult stock was one of the subject to be critically reviewed so that the assessment could be improved. Intuitive doubt for the abnormally high Fs comes from the fact that under such high Fs, e.g. 0.74 in 1987 for the total North Atlantic or 0.73 in 1986 for the South Atlantic (ICCAT 1989), virtually no possible adult fish will be in existence by 1990 (Suzuki and Miyabe 1990). This contradiction is averted later simply inflating the stock size or reducing the Fs for the adult stock estimated in the previous assessments.

In the previous study (Suzuki and Miyabe 1990), it was hypothesized that ignoring possible growth difference by sex for this species (e.g., Berkeley and Houde 1983) and further inferred from heterogeneous sex ratio, was one of the plausible sources of too high Fs. Although the aging of the Atlantic swordfish has not been validated, there is some indication that the circles on

spine sections of the Atlantic swordfish might be real annuli (Ehrhardt ms).

The present paper tried to simulate the observed sex ratio in function of size of the fish by introducing differential growth coefficient (K) and in addition, differential natural mortality coefficient (M) by sex.

The authors would like to express their gratitude to S. Berkeley and G. Scott for providing useful information on growth and sex ratio of the Atlantic swordfish. S. Tsuji kindly wrote a simulation program for this study.

Materials and methods

To be consistent with the previous study (Suzuki and Miyabe 1990), the same data sets were used in this study, i.e., the sex ratio in function of the length of the fish (Garcia and Mejuto 1988) as a reference and the von Bertalanffy growth parameters (VBGF) by sex (Berkeley and Houde 1983). In addition, sex pooled VBGF (Berkeley and Houde 1981) was used for checking the possible impact of sex specific M on resultant sex ratio by size. For simplicity, a value of 0.2 was arbitrarily used as the fishing mortality coefficient for both sexes regardless of age. Preliminary analysis indicated the results of the simulation was rather insensitive to the arbitrary choice of the fishing mortality coefficient.

As for sex and age specific Fs, those estimated for the north Atlantic in the previous study (Suzuki and Miyabe 1990) were cited. They are two sets of sex and age specific F vectors estimated for 1987, one for flat-top type, the other for dome-shaped type (Table 1). For ages 0 and older than 10, value for age 1 and value for age 10 were used, respectively.

The present study briefly touches on the subject whether or not the observed sex ratio shows a general consistency with exceed of male over female for the size class between about 140 and 160 cm in lowjaw-fork length (LJFL). Then, the following 5 combination of parameters were input in a simple growth-mortality simulation model with respect to the observed sex ratio:

- 1) Sex specific K with a constant M and F for both sex
- 2) Sex specific M with a constant K and F for both sex
- 3) Sex specific K and M with a constant F for both sex
- 4) Sex specific K and M with sex and age specific flat-top F
- 5) Sex specific k and M with sex and age specific dome-shaped F

The parameters used are summarized in Table 1.

The model starts with a unit of recruitment (one million fish) and calculates the survival numbers of the male and female which decrease exponentially. The fish recruit to the fishery once at fixed time in a year and the catches in number at age with age specific variance in length at given age were normally

distributed using random numbers. Age specific variance of length was assumed to increase with increase of age logarithmically (McCaughran 1981). In this simulation, age specific variance of $2 \cdot \log(LJFL)$ for each age was used. The calculation covers for ages 0 through 20.

Results and discussion

Information on sex ratio

Hoey (1986) reviewed the sex ratio of the species including the US commercial, recreational and research fishing as well as Cuban and Canadian fishery data. He pointed out that in the US swordfish data there were considerable variation among the areas and seasons for the observed sex ratio by size of the Atlantic swordfish. Table 2 shows Table 1 of Hoey (1986) with chi-square values for the US fisheries. Although the original data are expressed by dressed weight and might be subject to large variation in converting them into the corresponding lowjaw-fork length, a category of 50-99 pound in dressed weight roughly corresponds that of 140-170 cm LJFL (Miyake et al. 1988). The samples obtained from South Atlantic Bight with the largest sexed weight data showed highly significant male domination for a category of 50-99 pound dressed weight. For North Atlantic Bight, on the contrary, female domination for this category but only barely significant at 5 % significance level. The rest of areas, both for the Gulf Mexico and Grand Bank areas, showed no deviation of sex ratio from 1 to 1. However, the number of samples for those two areas are far smaller than that for the South Atlantic Bight. Garcia and Mejuto (1988) showed statistically significant excess of the male for a LJFL class of 150-170 cm taken in the Eastern-Central North Pacific.

The two papers cited above seem to be based on the most extensive data so far available which tend to support the domination of the male over the female for the length class between 140-160 LJFL. There are several other data available but they are either with small samples or collected from limited time-area strata and sometimes give us a conflicting indication. Therefore, although more studies be made before any definite conclusion is drawn, it was hypothesized that the male domination in the length class under the question was a consistent phenomenon if sufficiently large sampling were made.

Calculated sex ratios

Figure 1, cited from the work by Garcia and Mejuto (1988) is shown as the reference of the sex ratio in function of the LJFL for comparison with the results of simulated sex ratios under various parameter combinations (Figs. 2-6).

The excess of the male was observed in the Cases 1 and 4 (Figs. 2 and 5). As for the Case 1, although the excess was observed, maximum of the male domination was around 0.45 in terms of sex ratio which appeared to be smaller compared with

that of Garcia and Mejuto (1988). In addition, a bottom of the ratio is located at around 170 cm whereas it seems to be around 140-150 cm in the reference by Garcia and Mejuto (1988). In the Case 5, the male domination was too strong and female domination occurred for smaller fish less than 110 cm as well as for larger fish over 180 cm. The female domination for the smaller fish class is due to unbalance of Fs between sex (Table 1) which gave larger number of the female catch than the male.

No excess of the male was observed in the Cases 2, 3 and 5 (Figs. 3, 4, and 6). The sex ratio increased monotonously with the increase of length for Case 2 (Fig. 3) while a decrease of sex ratio, but the ratio is higher than 0.5, somewhere around 100 cm (Case 3, Fig. 4) and 150 cm (Case 5, Fig. 6) was observed.

The results does not appear to simulate the referred sex ratio satisfactorily. However, without assuming the sex specific growth, the observed sex ratio phenomenon may not be reproduced. It could be possible to assume sex and age specific natural mortality coefficients with a sex pooled growth coefficient which produce the excess of the male in the size range under the question but so far there is no circumstantial evidence to support that assumption.

Fishing mortality coefficient in recent years

The possibility of overestimation of the Fs for the larger fish was already mentioned previously. It is pertinent again to remind this in reference to the result of the latest stock assessment. The 1988 catch and the population size at the beginning of 1989 for the Northwest stock which was calculated by a high fishing mortality coefficients (0.99) estimated for the adult stock (ICCAT 1990):

	Unit:No. of fish			
	Age			
	6	7	8	9+
Catch in 1988	7326	3969	1896	4951
Stock size in 1989	8522	3939	2134	3635

Although catch of the adult fish is on decrease in recent years, it appears fairly possible that the catch at age in 1989 exceeds (or near equal to) the stock size in 1989. The Atlantic swordfish has been mainly exploited by longlining. Given passive nature of the longline fishing and wide horizontal and vertical habitats as well as fairly large spawning areas for the Atlantic swordfish, it is rather hard to imagine the present level of high exploitation of this stock.

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Table 1. Parameters used in the present study

	Male	Female	Male+Female							
Natural mortality coefficient (M)*	0.27	0.14	0.16							
Growth (VBGP)*										
L(inf.:cm)	217.36	340.04	297.10							
k	0.1948	0.09465	0.1054							
t(0)	-2.0444	-2.5912	-2.8672							
Fishing mortality coefficient (F)	0.20	0.20	0.20							
Sex and age specific fishing mortality coefficient (F) in 1987**										
	Age									
	1	2	3	4	5	6	7	8	9	10+
Flat-top										
Male	0.01	0.20	0.34	0.49	0.56	0.59	0.57	0.60	0.60	0.60
Female	0.07	0.13	0.18	0.31	0.42	0.47	0.50	0.50	0.50	0.50
Dome-shaped										
Male	0.08	0.17	0.26	0.36	0.39	0.37	0.32	0.27	0.18	0.13
Female	0.07	0.12	0.15	0.25	0.30	0.29	0.24	0.16	0.11	0.06

* Berkeley and Houde (1981)

**Suzuki and Miyabe (1990)

Table 2. Numbers, percentage and 1 to 1 chi-square values of male and female swordfish by region and size category

Region	0-49 lbs		50-99 lbs		100 lbs+	
	male	female	male	female	male	female
Gulf No.	46	53	36	40	14	79
%	46	54	47	53	15	85
Chi-sq.	0.49		0.21		45.43**	
SAB No.	217	149	219	48	113	140
%	59	41	82	18	45	55
Chi-sq.	12.63**		109.52**		2.88	
NAB No.	34	33	32	50	18	40
%	51	49	39	61	31	69
Chi-sq.	0.01		3.95*		8.34**	
GB No.	20	25	46	43	8	57
%	44	56	52	48	12	88
Chi-sq.	0.56		0.10		36.94**	

Original data cited from Table 1 of Hoey (1986).
 Gulf, SAB, NAB and GB denote the Gulf of Mexico, South Atlantic Bight, North Atlantic Bight and Grand Bank. Asterisks * and ** denote significant at 5 and 1 % level.

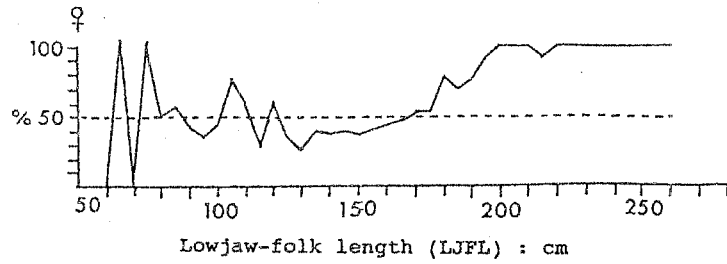


Figure 1. Percentage of female to male plus female with length of swordfish in the North Atlantic (after Garcia and Mejuto (1988)).

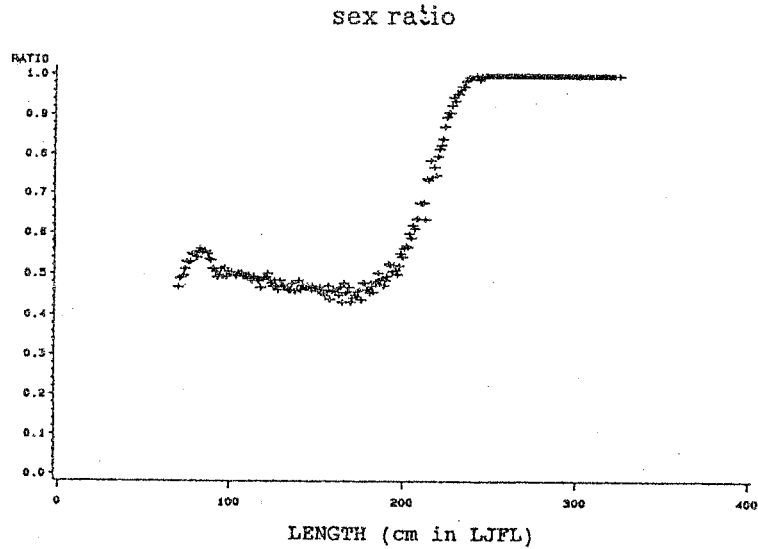


Figure 2. Simulated sex ratio with length of the Atlantic swordfish with differential growth rates and the same natural mortality rate by sex.

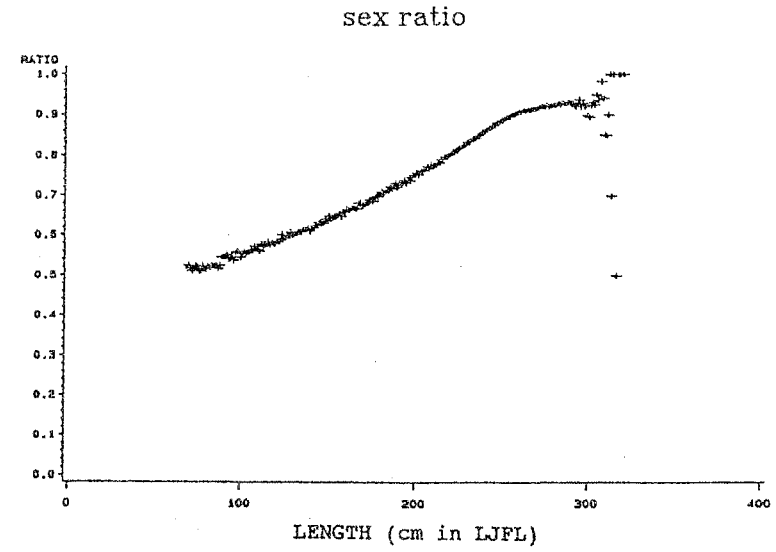


Figure 3. Simulated sex ratio with length of the Atlantic swordfish with the same growth rate and the differential natural mortality rates by sex.

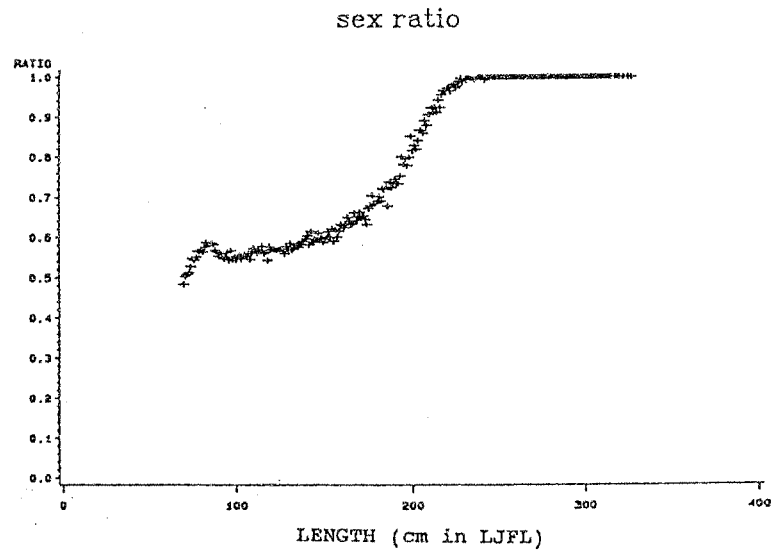


Figure 4. Simulated sex ratio with length of the Atlantic swordfish with the differential growth and differential natural mortality rates by sex.

sex ratio

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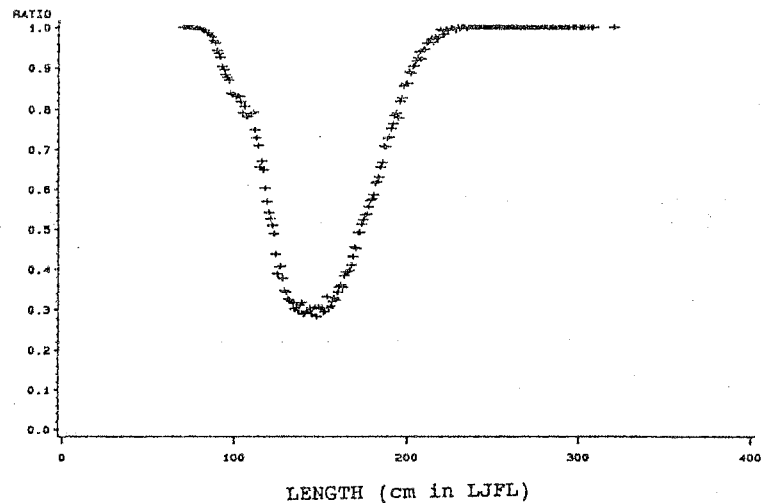


Figure 5. Simulated sex ratio with length of the Atlantic swordfish with sex specific growth and natural mortality rates and sex and age specific flat-top type of fishing mortality rates.

sex ratio

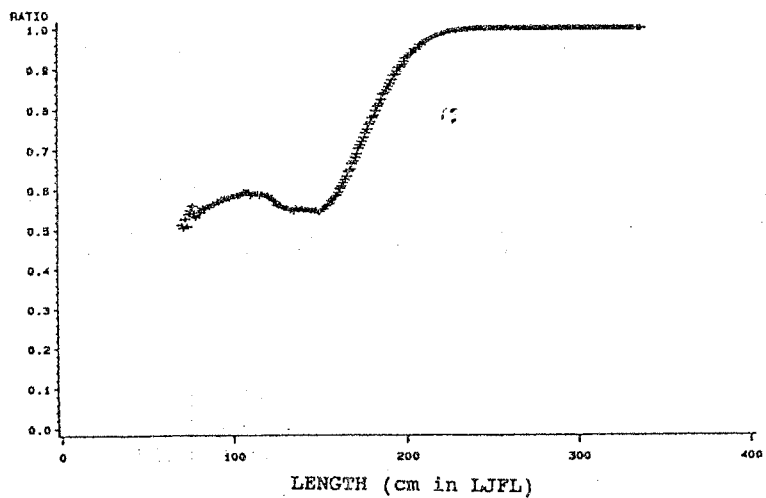


Figure 6. Simulated sex ratio with length of the Atlantic swordfish with sex specific growth and natural mortality rates and sex and age specific dome-shaped type of fishing mortality rates.