

LITERATURE REVIEW OF DIFFERENTIAL GROWTH AND MORTALITY IN ATLANTIC SWORDFISH, XIPHIAS GLADIUS

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INTRODUCTION

The current swordfish, *Xiphias gladius*, assessment relies on age-based models, but does not take into account sex-specific size dimorphism. Evidence accumulated from the earliest days of the harpoon fishery has suggested that sex specific size dimorphism occurs in swordfish, females being larger than males. This dimorphism may be the result of differential mortality, differential growth or both. In many cases (for example, a size selective fishery) differential growth could have a significant effect on fishing and/or natural mortality estimates.

A literature survey has been conducted in order to review the accumulated evidence for differential mortality and growth by sex in swordfish. There must be increased effort in the collection of sex-ratio, fecundity, ageing and length-frequency data.

DIFFERENTIAL MORTALITY BY SEX

Richard Lee (1942) of Wood's Hole, Massachusetts examined the gonads taken from 13 swordfish harvested during the summer harpoon fishery off the coast of New England. Lee was surprised to find that all 13 fish were female. He acknowledged the unlikelihood of collecting only females over such a wide area and time period and gave the probability of this occurring by chance as 0.5^{13} . Lee concluded, therefore, that either sexual segregation was occurring or there existed a very high ratio of female to male swordfish in the population. In support of Lee's work, Canadian swordfishermen reported that the reproductive organs of all fish taken by harpoon look similar (Tibbo et al. 1961). In addition to being exclusively female, fish from the harpoon fishery are most often large with few fish below 65 kg in weight being captured by this method (Beckett and Tibbo 1968).

The rapidly developing longline fishery provided conclusive evidence of size by sex dimorphism in swordfish since very few males were caught which were greater than 200 cm LJFL (approx. 76 kg dressed weight). Beckett (1972) noted that sex-ratios appeared to differ with water temperature as well as size. Males predominated in the Carribean fishery and few males were caught in waters colder than 18°C. Beckett suggested that large fish (females) feed at depth and digest in the warmer surface waters. Although evidence to support this claim is scarce, the fact that the harpooned fish in Beckett's study had either full or very empty stomachs makes the surface digestion theory compelling. Whatever the causative factors, it is apparent that the mortality by fishing in the harpoon fishery is much higher for females and quite probably female-specific.

Conser et al. (1986) determined fishing mortality rates for male and female swordfish using virtual population analysis (VPA). The authors found that the overall female spawning stock biomass had declined by over 40 % in six years (1978-1984). The fishing mortality, therefore, appears to be higher overall for females than for males. These results are supported by ICCAT (Anon. 1989). In contrast, evidence suggests that natural mortality is higher for male than for female swordfish. Berkeley and Houde (1981) used anal fin spines to age swordfish in the Straits of Florida. They found clear differences in the growth dynamics of male and female swordfish and concluded that male swordfish have a shorter lifespan and a higher natural mortality rate. Previous research carried out off the coast of Cuba by Guitart-Manday (1964) suggested that the population was composed of a large number of younger males and few adults. A much larger proportion of males (72%) than females (28%) were caught in the Cuban fishery. The author, in the absence of growth-by-age studies, assumed that smaller fish were younger fish and did not address the possibility of divergent growth rates in swordfish.

DIFFERENTIAL GROWTH BY SEX

Circumstantial evidence exists suggesting a difference in growth rates between male and female swordfish. Kume and Joseph (1969) examined the modal length values by sex of swordfish caught by the Japanese Pacific longline fleet and found that females grew more rapidly than males. Berkeley and Houde's (1981) ageing study of swordfish in the Florida straits revealed differences in the growth rates of male and female swordfish. Like Kume and Joseph, Berkeley and Houde also found that females grew more rapidly than males. Berkeley and Houde (1983), using fin spine sections, and Radtke and Hurley (1983) and Wilson and Dean (1983), using otoliths, all reported that females grow faster than males and reach a larger size. Although these studies are in agreement in principle, the calculated growth rates differ and more work is necessary before the theory of differential growth can be fully documented. It should be noted that taking differential growth into account significantly alters the results of fishing mortality calculations for swordfish (Suzuki and Miyabe 1990).

CONCLUSIONS

It appears, from the brief literature on the subject, that the marked size differences between male and female swordfish are due to a combination of differential growth and mortality rates. More research is required in order to assess the single and combined effects of these growth and mortality differences. Ideally, this research should be directed towards improving ageing techniques

and increasing the sample size of sexed and measured fish over a large area and time period. In the meantime, sex-ratio differences should be incorporated in the age-based assessment models.

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- Berkeley, S.A. and E.D. Houde (1981). Swordfish, Xiphias gladius dynamics in the Straits of Florida. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 15: 372-380.
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- Lee, R.E. (1942). The occurrence of female swordfish in southern New England waters with a description of their reproductive condition. *Copeia* 2: 117-119.
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- Kume, S. and J. Joseph (1969). Size compositions and sexual maturing of billfish caught by the Japanese longline fishing in the Pacific East of 130 West. Bull. Far Seas Fish. Res. Lab. 2: 115-160.
- Radtke, R.L. and P. Hurley (1983). Age estimation and growth of broadbill swordfish, Xiphias gladius, from the northwest Atlantic based on external features of otoliths. U.S. Dept. Commer. NOAA Tech. Rep. NMFS 8: 145-150.
- Suzuki, Z. and N. Miyabe (1990). Heterogeneous sex ratio of Atlantic swordfish and the implication to cohort analysis. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 32: 377-386.
- Tibbo, S.N., L.R. Day and W.F. Doucet (1961). The swordfish, Xiphias gladius, its life-history and economic importance in the Northwest Atlantic. Bull. Fish. Res. Bd. Can. No. 130, 47 pp.
- Wilson, C.A. and J.M. Dean (1983). The potential use of Sagittae for estimating age of Atlantic swordfish, Xiphias gladius. U.S. Dept. Commer. NOAA Tech. Rep. NMFS 8: 151-156.

ANNOTATED BIBLIOGRAPHY

- Beckett, J.S. (1972). Biology of swordfish, Xiphias gladius, in the Northwest Atlantic Ocean. U.S. Dep. Commer. NOAA Tech. Rep. International Billfish Symposium. Kailua-Kona, Hawaii, 2: 103-106.
- Fish under 160 cm are mostly males and are most commonly found in waters above 18°C.
 - Females are larger and are found in colder waters often at the surface, presumably digesting - stomachs were either full or very empty.
 - There have been recoveries of 18.3 % of harpoon tagged fish all within 200 miles of where they were tagged.
- Beckett, J.S. and S.N. Tibbo (1968). Recent changes in composition of Canadian Atlantic swordfish catches. ICNAF Redbook 3: 62- 66.
- The introduction of the longline fishery in 1962 led to a reduction in overall fish size due to changes in sex-ratio of caught fish as well as increased fishing intensity and size of the area fished.
 - Harpooned fish were large and exclusively female with few fish under 65 kg. In contrast fish from the longline fishery included males and smaller females.
- Berkeley, S.A. and E.D. Houde (1981). Swordfish, Xiphias gladius dynamics in the Straits of Florida. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 15: 372-380.
- "Female swordfish grow to a larger asymptotic size than do males and apparently have lower natural mortality rates and longer total lifespans."

- "Clear differences in growth dynamics between the sexes, males predominated in the catch by 2 to 1 until age 7 when females predominate" . Is there higher male mortality?
- Any analysis of age and growth should consider the sexes separately.

Berkeley, S.A. and E.D. Houde (1983). Age determination of broadbill swordfish, Xiphias gladius from the Straits of Florida using anal fin spine sections. U.S. Dept. Commer. NOAA Tech. Rep. NMFS 8: 137-143.

- Found anal fin spines to be appropriate ageing structures. Problems included multiple bands and loss of readability in older fish.
- The linear relationship between spine radius and LJFL was strong (0.94).
- There is a marked difference in growth rate between males and females; females grow faster after estimated age 2 and reach a larger size than males. Report faster growth rates after age 3 than other studies.
- Research requires a larger sample size and verification with otoliths. Tag and recapture is suggested as the most hopeful validation method.

Cavaliere, A. (1963). Studi sulla biologica pesca de Xiphias gladius nota II Boll. Pesca Pisc. Idrobiol. 18: 143-170. Transl. Fish. Res. Bd. Can. Transl. Ser. 2298.

- A summary of biological and oceanographic data from the swordfishery in the Straits of Messina.
- Found that larger fish were almost always female while smaller fish were mostly males and lesser in number.

Conser, R.J., P.L. Phares, J.J. Hoey and M.I. Farber (1986). An assessment of the status of stocks of swordfish in the northwest Atlantic Ocean. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 25: 218-245.

- Uses virtual population analysis (VPA) to determine fishing mortality (F) and stock size.
- Found that female spawning stock has declined markedly over the period 1978 - 1984. Suggests an overall decline of spawning stock of over 40 percent.
- Calls for routine collection of sex-ratio data.

Garcia, B. and J. Mejuto (1988). Primeros datos sobre la biologia de la reproduccion del pez espada, Xiphias gladius de las areas 35-45 N, 10-40 W. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 27: 164-177.

- Found male to female ratios of 1 to 1 for fish < 145 cm LJFL. For sizes 150 < LJFL < 170 cm, the male to female ratio was 1.5 to 1. Almost all fish larger than 200 cm were females.

Guitart-Manday, D. (1964). Biologia pesquera del emperador o pez espada, Xiphias gladius Linnaeus (Teleostomi: Xiphidae), en Las Aguas de Cuba. Poeyana, Ser B., No. 1 37 p. Trans. by Fish. Res. Bd. Can. Trans. Ser. 611.

- Research carried out on the swordfish longline fishery off the North coast of Cuba.
- A much larger proportion of males to females were caught (72 vs 28 percent).
- Concluded that the population was composed of many young males and few adults, the majority of which are female.
- Does not address the subject of differential growth rates.

Kuma, S. and J. Joseph (1969). Size compositions and sexual maturing of billfish caught by the Japanese longline fishing in the Pacific east of 130 west. Bull. Far Seas Fish. Res. Lab, 2: 115-160.

- The proportion of males to females was equal over the 130 to 170 cm size range. Above 170 cm, the proportion of females was progressively higher.
- Modal values analysis demonstrated that females grew more rapidly than males.

Lee, R.E. (1942). The occurrence of female swordfish in southern New England waters with a description of their reproductive condition. Copeia. 2: 117-119.

- Examined the gonads from 13 fish taken by harpoon off the New England coast.
- All 13 fish were female - "This is far beyond the realm of probability."
- Suggested sexual segregation or a high ratio of female to male fish in the population.

Palko, B.J., G.L. Beardsley and W.J. Richards (1981). Synopsis of the biology of the swordfish, Xiphias gladius Linnaeus. U.S. Dep. Commer. NOAA Tech. Rep. NMFS Circ. 441: 21 pp.

- Reviews what is known on maturity, growth rate, sex-ratio.
- "Recent research indicated that males mature at a smaller size than females.
- Good description of swordfish gonads for sexing purposes.

Radtke, R. and P. Hurley (1983). Age estimation and growth of broadbill swordfish, Xiphias gladius from the northwest Atlantic based on external features of otoliths. NOAA Tech. Rep. NMFS 8: 145-150.

- S.E.M. techniques were employed to examine the internal and external morphology of otoliths for possible ageing marks.
- Sagittae only were used as they are the largest and least fragile of three otolith bones.
- There was large intraspecific variation in otolith morphology.
- Slower growth rates were indicated than in previous studies. Different growth rates were indicated for males and females: females grow faster and to a larger size than do males.
- Validation is considered essential.

Suzuki, Z. and N. Miyabe (1990). Heterogeneous sex ratio of Atlantic swordfish and the implication to cohort Analysis. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 32: 377-386.

- The possible effects of ignoring differential growth by sex on cohort analysis of swordfish.
- Taking differential growth into account significantly lowers the fishing mortality coefficients for swordfish.

Tibbo, S.N., L.R. Day and W.F. Doucet (1961). The swordfish, Xiphias gladius, its life-history and economic importance in the Northwest Atlantic. Bull. Fish. Res. Bd. Can. 130: 47 p.

- An excellent summary of the Canadian swordfish fishery up to 1961.
- Notes that Canadian fishermen have said that all reproductive organs look the same suggesting that all fish from the harpoon fishery are female (or at least the same sex).

Wilson, C.A. and J.M. Dean (1983). The potential use of sagittae for estimating age of Atlantic swordfish, Xiphias gladius. U.S. Dept. Commer. NOAA Tech. Rep. NMFS 8: 151-156.

- Compared results of ageing using sagittae with results from fin spines of the same fish and found good agreement (91%).
- Swordfish sagittae were morphologically different from those of Istiophorids.
- Female swordfish have faster growth rates and grow to a larger size than do males. Estimates of length-at-age higher at size than previous estimates.
- Otolith growth indicates highly variable individual growth rates; therefore, lengths and weights may not be good estimators of swordfish age.
- Otoliths and fin spines are good complementary structures for swordfish ageing.