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Length Distributions of Female and Male Swordfish, Xiphias gladius, Captured in the Directed Hawaii Pelagic Longline Fishery During 1994-2008

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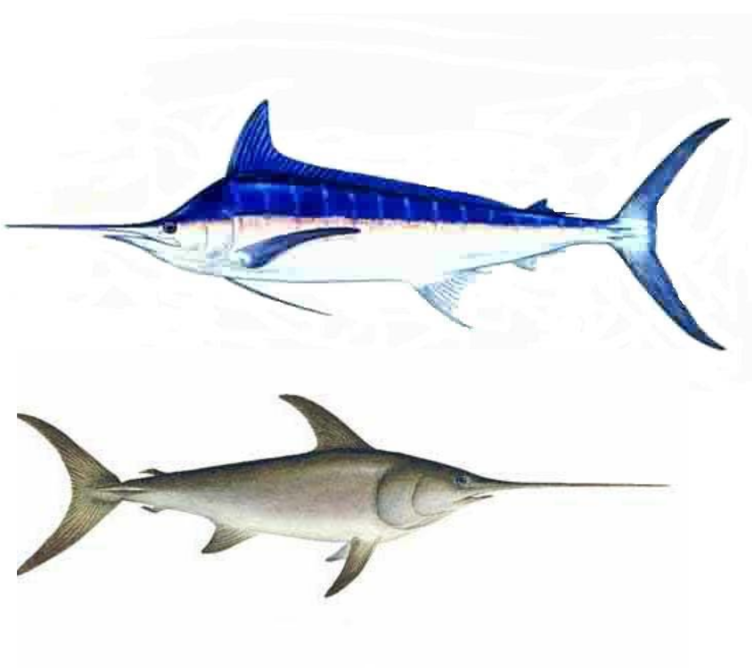

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Length distributions of female and male swordfish, *Xiphias gladius*, captured in the directed Hawaii pelagic longline fishery during 1994-2008

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Abstract

Age and growth studies of swordfish captured in the Hawaii-based pelagic longline fishery have shown that swordfish in this fishery region exhibit sexual dimorphism with females growing faster and attaining larger sizes than males (DeMartini et al. 2007). In this working paper, quarterly length distributions of swordfish captured in the Hawaii longline fishery on directed swordfish sets during 1994-2008 are described using data collected by fishery observers. Differences in quarterly mean lengths of female and male swordfish were analyzed using the two-sample T-test to discern whether sexual dimorphism was apparent in the directed swordfish fishery catch data. Overall, the analysis provided strong evidence that sexual dimorphism typically exists in the swordfish captured by the directed Hawaii longline fishery.

Materials and Methods

Swordfish length data were extracted from the PIFSC pelagic longline fishery database on 10-Jan-2009 for analyses. Only data collected by observers on directed, non-experimental sets were used. In particular, directed sets were defined as shallow sets that deployed less than 15 hooks per float. Length distributions were summarized for females, males, and all swordfish (females, males and unsexed fish) categories by year and quarter during 1994-quarter 1 (Q1), through 2008-quarter 3 (Q3). Year-quarter combinations that did not have at least 5 lengths for each sex were not included in the summaries or tested for differences in mean length. In particular, the swordfish length data were available for 1994-Q1 to 2001-Q2, 2004-Q4 to 2006-Q1, and 2007-Q1 to 2008-Q3; time periods without data corresponded to closures of the directed swordfish fishery to mitigate sea turtle interactions.

Swordfish length distributions for pooled sex and unsexed swordfish were determined from the directed fishery data. There were a total of 61,868 swordfish lengths collected in 43 quarters. Quarterly sample sizes ranged from n=29 to n=11,161 swordfish (Figure 1.1). Mean swordfish length by quarter ranged from 99.2 cm to 160.8 cm with an unweighted average of 142.3 cm (Figure 1.2) and had a significant increasing time trend (P=0.03). Coefficients of variation CVs) of quarterly length ranged from 14% to 29% with an average of 21%.

Swordfish length distributions for female and male swordfish were also determined from the shallow set longline data. There were a total of 15,993 female and 13,653 male swordfish lengths collected in 43 quarters (Figure 2.1). Quarterly sample sizes ranged from n=7 to n=2,445 for females and from n=5 to n=2,005 for males. Mean female swordfish length by quarter ranged from 111.4 cm to 184.6 cm with an average of 153.0 cm (Figure 2.2) and had a significant increasing time trend (P=0.01). In comparison, mean male swordfish length by quarter ranged from 81.0 cm to 159.8 cm with an average of 139.6 cm (Figure 2.3) and also had a significant increasing time trend (P=0.03). CVs of quarterly female length ranged from 13% to 29% with an average of 19%; for males, CVs ranged from 10% to 26% with an average of 17%. Overall, female length distributions appeared to have larger quarterly mean lengths and similar CVs in comparison to male length distributions.

Quarterly mean lengths of females (μ_F) and males (μ_M) were compared using the two-sample T-test for each quarter. This test procedure is robust to departures from normality. The test statistic (T) was the effect size (difference in means) divided by the precision

$$T = \frac{L_F - L_M}{S_P\sqrt{1/n_F + 1/n_M}} \tag{0.1}$$

where L_F and L_M were observed mean lengths of females and males, n_F and n_M were the sample sizes of females and males, and S_P was the pooled variance. An experiment-wise Type I error rate of $\alpha = 0.05$ was chosen for the 43 unplanned comparisons of means by quarter. A comparison-wise error rate of $\alpha^* = 0.001$ was used to judge the significance of individual two-sided tests, where the comparison-wise error rate was calculated using Dunn-Sidak's exact method with $\alpha^* = 1 - (1-\alpha)^{\frac{1}{43}}$ (Sokal and Rohlf 1981).

Results

Results indicated that there were 30 significant comparison-wise differences between female and male mean lengths (Table 1) with females being captured at larger average sizes. The observed percentage of significant comparisons (70%) was substantially higher than expected due to random sampling (5%). Overall, the analysis provided strong evidence that sexual dimorphism typically exists in the swordfish captured by the directed Hawaii longline fishery. This suggests that sex-specific fishery catch statistics need to be collected on an ongoing basis to account for expected differences in female and male size at capture.

References

DeMartini, E., J. Uchiyama, R. Humphreys, Jr., J. Sampaga, and H. Williams. 2007. Age and growth of swordfish (*Xiphias gladius*) caught by the Hawaii-based pelagic longline fishery. Fish. Bull. 105:356-367.

Sokal, R., and F. Rohlf. 1981. Biometry, 2nd Ed. W.H. Freeman & Co., New York, 859 p.

Table 1. Results of two-sample T-test of differences between female and male swordfish mean lengths by quarter during 1994-2008.

Time Period	Female Minus Male Mean Length	Precision of Effect Size	2-Sample T-Test Statistic	T-Distribution Two-Sided Experiment-Wise P-Value	Comparison-Wise Adjusted Significant ?
1994.125	12.2	2.8	4.42	0.000	Yes
1994.375	15.0	2.5	6.00	0.000	Yes
1994.625	-4.0	5.5	-0.73	0.467	
1994.875	8.0	3.0	2.67	0.008	
1995.125	6.2	2.1	2.92	0.004	
1995.375	11.7	2.2	5.32	0.000	Yes
1995.625	26.3	5.3	4.92	0.000	Yes
1995.875	31.4	15.4	2.03	0.062	
1996.125	13.6	5.7	2.40	0.018	
1996.375	14.7	3.6	4.04	0.000	Yes
1996.625	10.0	4.2	2.42	0.016	
1996.875	13.0	2.3	5.63	0.000	Yes
1997.125	16.0	1.7	9.34	0.000	Yes
1997.375	21.2	2.5	8.41	0.000	Yes
1997.625	10.4	2.0	5.24	0.000	Yes
1997.875	9.0	2.7	3.39	0.001	Yes
1998.125	12.4	1.9	6.50	0.000	Yes
1998.375	17.1	3.4	5.04	0.000	Yes
1998.625	3.7	3.0	1.25	0.211	
1998.875	10.1	1.6	6.30	0.000	Yes
1999.125	10.0	1.8	5.45	0.000	Yes
1999.375	17.2	2.5	6.81	0.000	Yes
1999.625	5.9	8.6	0.69	0.495	
1999.875	10.1	3.5	2.91	0.004	
2000.125	6.2	1.7	3.74	0.000	Yes
2000.375	18.6	1.8	10.39	0.000	Yes
2000.625	21.1	4.0	5.21	0.000	Yes
2000.875	9.0	1.8	5.01	0.000	Yes
2001.125	4.5	2.4	1.90	0.059	
2001.375	48.6	9.2	5.28	0.000	Yes
2001.625					
2001.875					
2002.125					
2002.375					
2002.625					
2002.875					
2003.125					
2003.375					
2003.625					
2003.875					
2004.125					
2004.375					
2004.625					
2004.875	5.9	7.1	0.84	0.404	
2005.125	-3.0	3.2	-0.93	0.353	
2005.375	15.0	0.9	15.91	0.000	Yes
2005.625	8.7	2.8	3.09	0.002	
2005.875	10.3	2.2	4.75	0.000	Yes
2006.125	11.4	0.8	13.44	0.000	Yes
2006.375					
2006.625					
2006.875					
2007.125	11.7	1.2	9.94	0.000	Yes
2007.375	14.3	1.6	8.77	0.000	Yes
2007.625	15.6	4.7	3.33	0.001	Yes
2007.875	10.7	3.0	3.53	0.001	Yes
2008.125	9.6	1.1	8.40	0.000	Yes
2008.375	18.4	2.6	7.15	0.000	Yes
2008.625	35.2	5.6	6.33	0.000	Yes

Figure 1.1. Quarterly sample sizes used to characterize length distributions of all swordfish (pooled sexes and unsexed) captured in the directed Hawaii longline fishery.

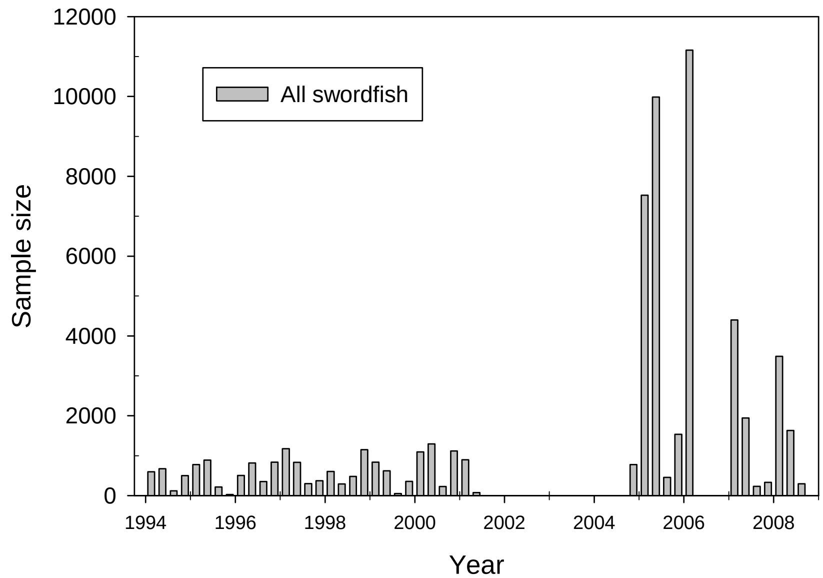

Figure 1.2. Observed quarterly mean lengths of all swordfish (solid circle) along with sample precision (± 1 standard deviation) captured in the directed Hawaii longline fishery.

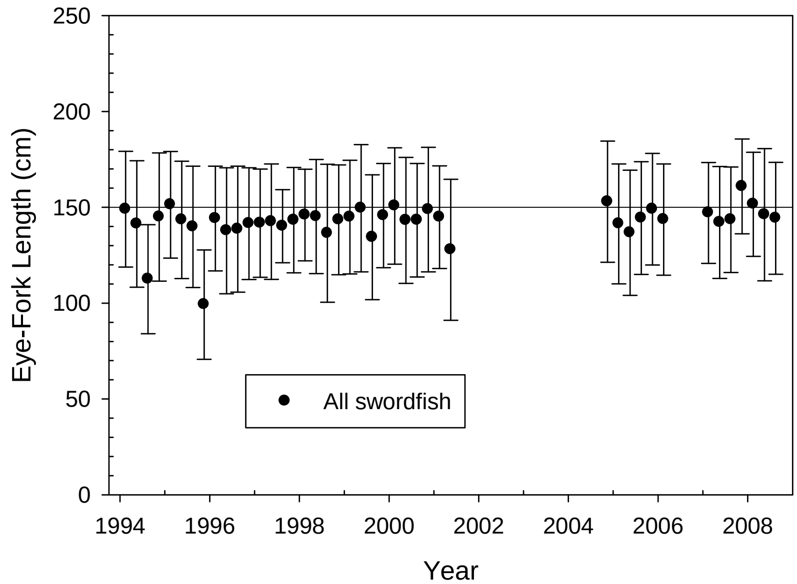

Figure 2.1. Quarterly sample sizes used to characterize length distributions of female and male swordfish (pooled sexes and unsexed) captured in the directed Hawaii longline fishery.

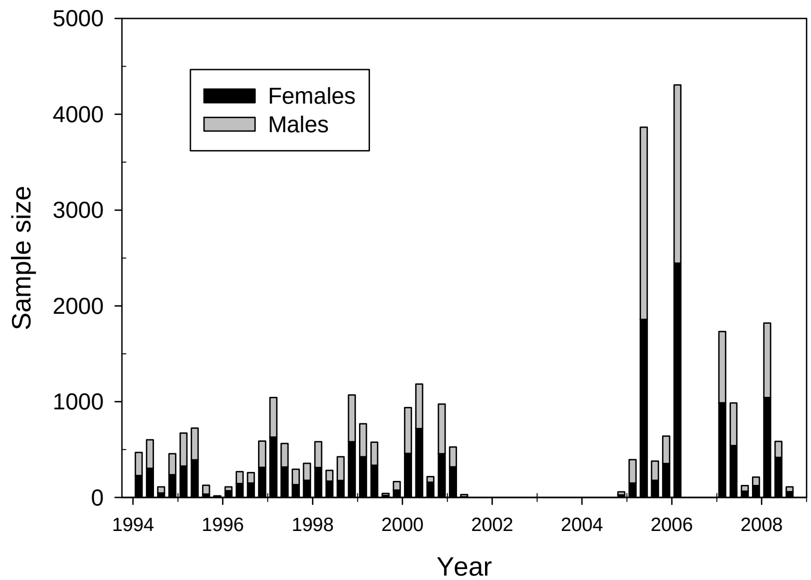

Figure 2.2. Observed quarterly mean lengths of female swordfish (solid circle) along with sample precision (± 1 standard deviation) in the directed Hawaii longline fishery.

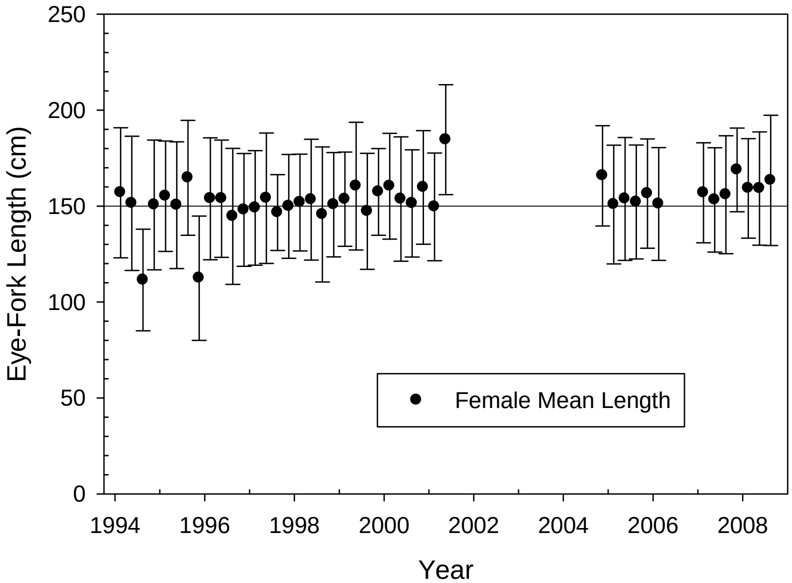

Figure 2.3. Observed quarterly mean lengths of male swordfish (solid circle) along with sample precision (± 1 standard deviation) in the directed Hawaii longline fishery.

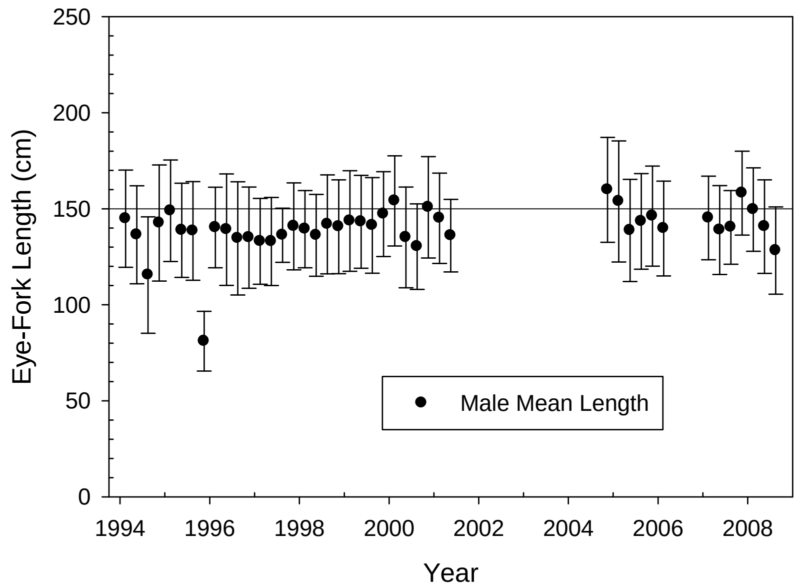

Figure 3. Observed effect size (solid) for two-sample T-test comparing mean lengths of female and male swordfish along with sample precision of effect size (± 1 standard deviation) in the directed Hawaii longline fishery.