**Swordfish (*Xiphias gladius*) Length Composition Data**

**for the Hawaii Longline Fishery during 1994-2022**

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動物, 魚 が含まれている画像

自動的に生成された説明

# **Abstract**

This working paper summarizes the available swordfish length composition data for swordfish caught in the Hawaii longline fishery. These data were prepared for submission to the November 2022 ISC Billfish Working Group data preparation meeting and application in the 2023 benchmark stock assessment of Western and Central North Pacific swordfish. Swordfish (*Xiphias gladius*) size frequency data were collected for the Hawaii-based longline fishery during 1994-2022 based on the current Pacific Islands Regional Observer Program (PIROP) data set. Length composition data were separated into shallow-set and deep-set longline sectors to account for differences in species targeting and operational characteristics by sector. The shallow-set longline sector targets swordfish while the deep-set sector typically targets big eye tuna and captures swordfish as bycatch. We evaluated annual and quarterly trends in observed mean lengths and calculated mean weights of swordfish and their variability. Summary length frequency tables showed the number of swordfish measured per 5-cm length bin by year, quarter, and fishery sector for stock assessment modeling. Empirical analyses showed that average size of swordfish captured in the shallow-set sector is consistently larger than in the deep-set sector. Quarterly mean lengths of swordfish in the shallow-set and deep-set sectors averaged 146 cm and 110 cm (eye-fork length) during 1994-2022 while calculated mean weights averaged 67.7 kg and 39.3 kg, respectively. Variability in the size of harvested swordfish was also lower for the shallow-set sector with coefficients of variation (CVs) for length and weight of 22% and 64% in comparison to CVs of 33% and 110% for the deep-set sector. Quarterly mean lengths were relatively stable across years for the shallow-set sector and were more variable for the deep-set sector with larger mean lengths observed in quarter 2. There was an increasing trend in mean lengths and weights of swordfish for both shallow- and deep-set sectors of the Hawaii longline fishery during 1994-2022. In particular, strong serial correlations were observed for annual mean lengths () and weights () of swordfish in both the shallow- ( and ) and the deep-set ( and ) longline sectors. We note that the increasing trend in the size of harvested swordfish across the swordfish-targeting shallow-set and tuna-targeting deep-set sectors suggests that some biological aspects of the Hawaii longline fishery system have changed, especially in recent years.

# **Introduction**

This working paper summarizes the available swordfish length composition data for swordfish caught in the Hawaii longline fishery. These size composition data were prepared for submission to the November 2022 ISC Billfish Working Group data preparation meeting and application in the 2023 benchmark stock assessment of Western and Central North Pacific swordfish. Swordfish (*Xiphias gladius*) size frequency data were collected for the Hawaii-based longline fishery during 1994-2022 based on the current Pacific Islands Regional Observer Program (PIROP) data set (PIRO 2017). Length composition data were separated into shallow-set and deep-set longline sectors to account for differences in species targeting and operational characteristics by sector. The shallow-set longline sector targets swordfish while the deep-set sector typically targets big eye tuna and captures swordfish as bycatch. We provide summaries of annual and quarterly mean lengths and their variability, as well as calculated mean weights, along with a table of swordfish length observations per 5-cm length bin by sector, year, and quarter. We also provide some empirical analyses of the available swordfish size composition data and its temporal patterns by sector in the Hawaii longline fishery.

# **Methods**

Observed eye-fork length (EFL) measurements of swordfish captured in the Hawaii longline fishery were gathered and summarized from the Pacific Islands Region Observer Program database. This summary included all available records of observed longline sets from 1994 to 2022 (Access 17 October 2022). A total of 132,619 swordfish lengths with reported hooks per float were available. The swordfish length data represented landings in both the shallow-set (< 15 hooks per float), or swordfish-targeting, and the deep-set (≥ 15 hooks per float), or tuna-targeting sectors of the Hawaii longline fishery since 2005 (Walsh and Brodziak, 2015). For longline data prior to 2005, the definition of shallow- and deep-set sector operations was determined with an empirical cutoff of 10 hooks per float based on the best available analyses of patterns of multispecies catches and species targeting in the Hawaii longline fishery reported in Sculley et al (2019) and used for the ISC striped marlin stock assessment. We also conducted a sensitivity analysis of the swordfish length composition data using a simplified definition of fishery sectors based on a uniform cutoff of 15 hooks per float for each longline set during 1994-2022. In this case, the magnitude of differences between the quarterly mean length summaries and correlation results with the current analytical cutoff and the simple 15 hooks per float cutoff are reported. Given that the deep-set sector incidentally catches swordfish as a bycatch species, one expects that the fishery selectivity at age and size composition of swordfish from the deep-set sector will differ from that of the shallow-set sector. In this context, we summarized the shallow-set and deep-set length data separately here as in previous swordfish size composition analyses due to the differences in spatial distributions, operations, and targeting of species between the two sectors of the longline fleet (Brodziak and Courtney 2009, Sculley et al. 2017, Sculley et al. 2018).

Estimates of the whole wet weights (*W*) of individual swordfish were calculated from the length data (cm, EFL) by converting observed lengths (*L*) to weights (kg) using the weight-length relationship from Uchiyama et al. (1999). This was the length-weight relationship used for female and male swordfish since the 2018 benchmark ISC stock assessment, where the predicted weight at observed length was given by

(1) 

We summarized swordfish mean length observations and calculated mean weights by year and quarter (Quarters are: 1 [Jan-Mar], 2 [Apr-Jun], 3 [Jul-Sep], and 4 [Oct-Dec]), by year, and by quarter for comparison in the shallow- and deep-set sectors. We evaluated whether there were any apparent trends in mean sizes and size variation of swordfish by year and quarter and by year using Pearson correlations (). The relative strengths of associations between quarterly or annual observations of mean lengths and calculated mean weights as well as their variability were also evaluated using correlation analyses.

# **Results**

The partitioning of the PIROP swordfish length dataset led to sample sizes of 118,117 and 14,432 observed swordfish lengths for the shallow- and deep-set sectors, respectively. Time series of mean lengths of swordfish by year and quarter were calculated for each sector (Tables 1 and 2). Mean lengths of swordfish were consistently greater in the shallow-set sector and averaged 146 cm during 1994-2022 in comparison to an average of 110 cm for the deep-set sector[[1]](#footnote-1). Mean lengths of swordfish harvested in the shallow-set sector were about 2 cm larger than the median length at maturity of about 144 cm for female swordfish (Figure 1a). In comparison, mean lengths of swordfish bycatch in the deep-set sector were substantially lower than the female length at 50% maturity with the exception of quarter 2 when larger swordfish were harvested (Figure 2b). Quarterly length distributions were also more variable for the deep-set sector, which had an average coefficient of variation for length (CV) of 33% in comparison to a CV of 22% for the shallow-set sector. Overall, swordfish harvested the shallow-set sector were larger and showed less variability in their length distributions than swordfish caught in the deep-set sector.

The swordfish quarterly mean length time series by sector both showed moderate increasing trends from the 1990s to the 2020s (Tables 1 and 2, Figure 1). For the shallow-set sector, quarterly mean lengths increased from an average of about 140 cm in the 1990s to over 150 cm in the 2020s (Table 1) and showed decadal increases of 4%, 1% and 4% in mean lengths from the 1990s to the 2020s. Mean lengths of swordfish showed a more increasing trend in the deep-set sector (Table 2), where the mean length averaged about 97 cm in the 1990s, increased to average about 108 cm (+11%) in the 2000s and then to average 113 cm (+5%) in the 2010s and over 130 cm in the early 2020s (Table 2 and Figure 1).

The swordfish calculated mean weight time series by quarter also showed similar trends by sector (Figure 2). The long-term average mean weight was about 67.7 kg for the shallow-set sector but was about 39.3 kg, or about 42% lower in the deep-set sector. The variability in calculated swordfish weights was greater for the deep-set sector, which had a CV for weight of about 110% in comparison to a weight CV of about 64% for the shallow-set sector. Annual time series of mean swordfish lengths and calculated weights showed increasing trends by sector (Figures 3 and 4) with relatively low variability in the annual mean lengths.

The quarterly distributions of mean lengths for the shallow-set sector were similar and fluctuated about an average of about 146 cm with CVs of length ranging from 20% to 23% by quarter (Figure 5a). In contrast, there was a seasonal pattern for the deep-set sector, where the mean lengths in quarter 2 were larger and averaged 145 cm, or roughly equal to the female length at maturity, in comparison to quarters 1, 3 and 4, which averaged 118, 91, and 86 cm, respectively (Figure 5b). Variability in the deep-set length distributions was also higher with CVs of length ranging from 32% to 48%. Quarterly distributions of calculated mean weights showed similar patterns for the shallow-set (Figure 6a) and deep-set sector (Figure 6b), but higher levels of relative variability due to the allometric scaling of weight with length.

The quarterly mean size distributions of swordfish by fishery sector exhibited positive associations in most cases (Table 3). Time series of mean lengths of swordfish by year and quarter showed positive serial correlations for both the shallow-set () and deep-set () sectors. The quarterly calculated mean weight time series also had positive serial correlations for the shallow- () and deep-set () sectors. In contrast, mean lengths were not associated with variability in length for the shallow-set sector (Table 3) but were positively associated with increasing variability for the deep-set sector. Mean lengths and weights were highly positively correlated for both sectors (), as expected, and the variabilities in the quarterly length and weight distributions were also strongly associated within the shallow- () and deep-set () sectors.

The annual mean size distributions of swordfish by fishery sector were also positively associated (Table 4). Annual time series of mean lengths of swordfish had strong positive correlations for both the shallow-set () and deep-set () sectors (Figures 3 and 4) and the same was true for the calculated mean weight series for the shallow- () and the deep-set () sectors[[2]](#footnote-2). Similar to the quarterly distributions, annual mean lengths were weakly associated with variability in length for the shallow-set sector (Table 4, ) but were strongly associated with increasing variability for the deep-set sector (Table 4, ). Annual mean lengths and weights of swordfish were highly positively correlated for both sectors (), as expected, and the annual variabilities in length and weight distributions were strongly associated for the shallow- () and the deep-set () sectors.

Overall, there was an increasing trend in mean lengths and weights of swordfish for both shallow- and deep-set sectors of the Hawaii longline fishery during 1994-2022. In particular, strong serial correlations were observed for annual mean lengths () and weights () of swordfish in both the shallow- ( and) and the deep-set ( and) longline sectors. We note that the increasing trend in the size of harvested swordfish across the swordfish-targeting shallow-set and tuna-targeting deep-set sectors suggests that some biological aspects of the Hawaii longline fishery system have changed, especially in recent years.

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**Table 1.** Swordfish mean lengths (cm, eye-fork-length [EFL]), coefficients of variation (CV) of length, and numbers of fish lengths sampled by year and quarter, for the **shallow-set sector** of the Hawaii longline collected by the Pacific Islands Regional Observer Program during 1994-2022.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 1994 | 1 | 149.0 | 0.20 | 600 |
| 1994 | 2 | 141.2 | 0.23 | 674 |
| 1994 | 3 | 112.4 | 0.25 | 119 |
| 1994 | 4 | 145.5 | 0.23 | 556 |
| 1995 | 1 | 151.3 | 0.18 | 777 |
| 1995 | 2 | 143.4 | 0.21 | 891 |
| 1995 | 3 | 139.7 | 0.23 | 218 |
| 1995 | 4 | 104.3 | 0.27 | 25 |
| 1996 | 1 | 144.1 | 0.19 | 506 |
| 1996 | 2 | 137.7 | 0.24 | 817 |
| 1996 | 3 | 138.7 | 0.24 | 349 |
| 1996 | 4 | 141.4 | 0.21 | 840 |
| 1997 | 1 | 141.7 | 0.20 | 1176 |
| 1997 | 2 | 142.5 | 0.21 | 835 |
| 1997 | 3 | 140.1 | 0.14 | 299 |
| 1997 | 4 | 143.3 | 0.19 | 372 |
| 1998 | 1 | 145.9 | 0.16 | 606 |
| 1998 | 2 | 145.1 | 0.21 | 292 |
| 1998 | 3 | 136.4 | 0.26 | 481 |
| 1998 | 4 | 143.4 | 0.20 | 1149 |
| 1999 | 1 | 144.8 | 0.20 | 837 |
| 1999 | 2 | 149.5 | 0.22 | 622 |
| 1999 | 3 | 134.3 | 0.24 | 50 |
| 1999 | 4 | 145.6 | 0.19 | 357 |
| 2000 | 1 | 150.2 | 0.20 | 1259 |
| 2000 | 2 | 143.1 | 0.23 | 1294 |
| 2000 | 3 | 143.2 | 0.21 | 229 |
| 2000 | 4 | 148.8 | 0.22 | 1118 |
| 2001 | 1 | 144.8 | 0.19 | 895 |
| 2001 | 2 | 130.8 | 0.29 | 63 |
| 2004 | 2 | 131.6 | 0.31 | 14 |
| 2004 | 3 | 138.7 | 0.30 | 6 |
| 2004 | 4 | 152.8 | 0.21 | 775 |
| 2005 | 1 | 141.3 | 0.22 | 7524 |
| 2005 | 2 | 136.7 | 0.24 | 9985 |
| 2005 | 3 | 144.4 | 0.20 | 458 |
| 2005 | 4 | 149.0 | 0.20 | 1538 |
| 2006 | 1 | 143.6 | 0.20 | 11224 |
| 2007 | 1 | 147.4 | 0.18 | 4578 |

**Table 2.** Continued.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 2007 | 2 | 141.8 | 0.21 | 2294 |
| 2007 | 3 | 143.9 | 0.19 | 236 |
| 2007 | 4 | 160.8 | 0.15 | 332 |
| 2008 | 1 | 151.8 | 0.18 | 3511 |
| 2008 | 2 | 146.2 | 0.24 | 1646 |
| 2008 | 3 | 144.2 | 0.20 | 298 |
| 2008 | 4 | 158.3 | 0.16 | 1285 |
| 2009 | 1 | 154.0 | 0.19 | 2701 |
| 2009 | 2 | 147.6 | 0.22 | 2785 |
| 2009 | 3 | 147.6 | 0.21 | 273 |
| 2009 | 4 | 161.0 | 0.19 | 615 |
| 2010 | 1 | 154.6 | 0.18 | 2900 |
| 2010 | 2 | 147.5 | 0.20 | 1686 |
| 2010 | 3 | 153.0 | 0.21 | 302 |
| 2010 | 4 | 158.7 | 0.19 | 831 |
| 2011 | 1 | 155.1 | 0.20 | 3134 |
| 2011 | 2 | 144.9 | 0.24 | 1453 |
| 2011 | 3 | 146.3 | 0.24 | 164 |
| 2011 | 4 | 156.9 | 0.19 | 678 |
| 2012 | 1 | 152.0 | 0.21 | 2651 |
| 2012 | 2 | 141.5 | 0.27 | 1393 |
| 2012 | 3 | 143.1 | 0.25 | 86 |
| 2012 | 4 | 151.3 | 0.19 | 654 |
| 2013 | 1 | 153.7 | 0.20 | 1751 |
| 2013 | 2 | 145.8 | 0.25 | 856 |
| 2013 | 3 | 140.4 | 0.27 | 24 |
| 2013 | 4 | 145.4 | 0.25 | 922 |
| 2014 | 1 | 151.0 | 0.23 | 2629 |
| 2014 | 2 | 144.7 | 0.25 | 1545 |
| 2014 | 3 | 153.0 | 0.22 | 266 |
| 2014 | 4 | 138.3 | 0.22 | 754 |
| 2015 | 1 | 143.8 | 0.21 | 3284 |
| 2015 | 2 | 139.6 | 0.23 | 1114 |
| 2015 | 3 | 135.4 | 0.25 | 142 |
| 2015 | 4 | 142.2 | 0.20 | 324 |
| 2016 | 1 | 146.4 | 0.19 | 1378 |
| 2016 | 2 | 138.9 | 0.25 | 962 |
| 2016 | 3 | 141.7 | 0.23 | 433 |
| 2016 | 4 | 151.5 | 0.17 | 390 |
| 2017 | 1 | 151.1 | 0.19 | 1856 |
| 2017 | 2 | 147.6 | 0.21 | 1711 |

**Table 3.** Continued.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 2017 | 3 | 152.1 | 0.19 | 185 |
| 2017 | 4 | 153.5 | 0.20 | 792 |
| 2018 | 1 | 153.8 | 0.20 | 1731 |
| 2018 | 2 | 134.2 | 0.28 | 168 |
| 2019 | 1 | 154.5 | 0.19 | 1397 |
| 2020 | 1 | 159.3 | 0.20 | 896 |
| 2020 | 2 | 155.6 | 0.19 | 67 |
| 2020 | 3 | 126.1 | 0.13 | 8 |
| 2020 | 4 | 149.8 | 0.21 | 622 |
| 2021 | 1 | 163.1 | 0.19 | 1387 |
| 2021 | 2 | 155.1 | 0.23 | 728 |
| 2021 | 3 | 133.5 | 0.47 | 2 |
| 2021 | 4 | 154.8 | 0.22 | 383 |
| 2022 | 1 | 163.3 | 0.20 | 2214 |
| 2022 | 2 | 158.1 | 0.22 | 720 |
| 2022 | 3 | 163.6 | 0.18 | 230 |
| 2017 | 3 | 152.1 | 0.19 | 185 |
| 2017 | 4 | 153.5 | 0.20 | 792 |
| 2018 | 1 | 153.8 | 0.20 | 1731 |
| 2018 | 2 | 134.2 | 0.28 | 168 |
| 2019 | 1 | 154.5 | 0.19 | 1397 |
| 2020 | 1 | 159.3 | 0.20 | 896 |
| 2020 | 2 | 155.6 | 0.19 | 67 |
| 2020 | 3 | 126.1 | 0.13 | 8 |
| 2020 | 4 | 149.8 | 0.21 | 622 |
| 2021 | 1 | 163.1 | 0.19 | 1387 |
| 2021 | 2 | 155.1 | 0.23 | 728 |
| 2021 | 3 | 133.5 | 0.47 | 2 |
| 2021 | 4 | 154.8 | 0.22 | 383 |
| 2022 | 1 | 163.3 | 0.20 | 2214 |
| 2022 | 2 | 158.1 | 0.22 | 720 |
| 2022 | 3 | 163.6 | 0.18 | 230 |
| Average 1994-1999 | | 140.1 | 0.21 | 560 |
| Average 2000-2009 | | 146.3 | 0.21 | 2190 |
| Average 2010-2019 | | 147.5 | 0.22 | 1158 |
| Average 2020-2022 | | 152.9 | 0.22 | 660 |
| Average 1994-2022 | | 145.9 | 0.22 | 1231 |

**Table 2.** Swordfish mean lengths (cm, eye-fork-length [EFL]), coefficients of variation (CV) of length, and numbers of fish lengths sampled by year and quarter, for the **deep-set sector** of the Hawaii longline collected by the Pacific Islands Regional Observer Program during 1994-2022.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 1994 | 1 | 113.0 |  | 1 |
| 1994 | 2 | 157.8 | 0.29 | 10 |
| 1994 | 3 | 67.9 | 0.25 | 14 |
| 1994 | 4 | 87.3 | 0.28 | 3 |
| 1995 | 1 | 94.0 | 0.29 | 3 |
| 1995 | 2 | 164.8 | 0.19 | 5 |
| 1995 | 3 | 70.3 | 0.45 | 26 |
| 1995 | 4 | 72.1 | 0.22 | 21 |
| 1996 | 1 | 92.3 | 0.30 | 3 |
| 1996 | 2 | 118.3 | 0.40 | 29 |
| 1996 | 3 | 82.0 | 0.24 | 4 |
| 1996 | 4 | 97.3 | 0.28 | 3 |
| 1997 | 1 | 78.0 | 0.13 | 2 |
| 1997 | 2 | 154.5 | 0.38 | 6 |
| 1997 | 3 | 72.0 | 0.04 | 2 |
| 1997 | 4 | 73.6 | 0.22 | 20 |
| 1998 | 1 | 76.9 | 0.24 | 9 |
| 1998 | 2 | 92.3 | 0.40 | 8 |
| 1998 | 3 | 64.2 | 0.25 | 27 |
| 1998 | 4 | 74.8 | 0.30 | 59 |
| 1999 | 1 | 111.2 | 0.39 | 11 |
| 1999 | 2 | 155.6 | 0.31 | 7 |
| 1999 | 3 | 65.7 | 0.20 | 22 |
| 1999 | 4 | 88.9 | 0.27 | 19 |
| 2000 | 1 | 124.7 | 0.37 | 7 |
| 2000 | 2 | 135.5 | 0.30 | 17 |
| 2000 | 3 | 74.5 | 0.52 | 41 |
| 2000 | 4 | 89.6 | 0.40 | 160 |
| 2001 | 1 | 112.0 | 0.26 | 49 |
| 2001 | 2 | 132.0 | 0.33 | 77 |
| 2001 | 3 | 90.7 | 0.43 | 141 |
| 2001 | 4 | 88.6 | 0.38 | 228 |
| 2002 | 1 | 124.4 | 0.29 | 487 |
| 2002 | 2 | 128.2 | 0.36 | 260 |
| 2002 | 3 | 86.4 | 0.40 | 204 |
| 2002 | 4 | 81.7 | 0.31 | 277 |
| 2003 | 1 | 117.4 | 0.30 | 74 |
| 2003 | 2 | 146.7 | 0.28 | 170 |
| 2003 | 3 | 69.3 | 0.33 | 681 |

**Table 2.** Continued.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 2003 | 4 | 79.7 | 0.28 | 441 |
| 2004 | 1 | 98.1 | 0.31 | 191 |
| 2004 | 2 | 111.9 | 0.44 | 472 |
| 2004 | 3 | 96.1 | 0.45 | 276 |
| 2004 | 4 | 83.8 | 0.32 | 382 |
| 2005 | 1 | 114.3 | 0.26 | 70 |
| 2005 | 2 | 153.3 | 0.25 | 216 |
| 2005 | 3 | 91.8 | 0.47 | 524 |
| 2005 | 4 | 85.3 | 0.29 | 479 |
| 2006 | 1 | 110.1 | 0.33 | 100 |
| 2006 | 2 | 134.5 | 0.35 | 162 |
| 2006 | 3 | 96.1 | 0.42 | 102 |
| 2006 | 4 | 94.9 | 0.32 | 119 |
| 2007 | 1 | 111.4 | 0.20 | 11 |
| 2007 | 2 | 127.2 | 0.39 | 126 |
| 2007 | 3 | 96.5 | 0.49 | 125 |
| 2007 | 4 | 81.9 | 0.36 | 238 |
| 2008 | 1 | 113.6 | 0.33 | 50 |
| 2008 | 2 | 168.8 | 0.22 | 233 |
| 2008 | 3 | 110.4 | 0.46 | 92 |
| 2008 | 4 | 92.5 | 0.34 | 61 |
| 2009 | 1 | 121.0 | 0.25 | 42 |
| 2009 | 2 | 141.6 | 0.33 | 123 |
| 2009 | 3 | 109.4 | 0.38 | 123 |
| 2009 | 4 | 99.5 | 0.35 | 62 |
| 2010 | 1 | 120.0 | 0.33 | 63 |
| 2010 | 2 | 146.0 | 0.30 | 185 |
| 2010 | 3 | 102.2 | 0.50 | 131 |
| 2010 | 4 | 82.5 | 0.37 | 141 |
| 2011 | 1 | 106.0 | 0.35 | 48 |
| 2011 | 2 | 158.7 | 0.25 | 67 |
| 2011 | 3 | 78.6 | 0.47 | 195 |
| 2011 | 4 | 78.6 | 0.24 | 120 |
| 2012 | 1 | 115.9 | 0.31 | 44 |
| 2012 | 2 | 135.7 | 0.38 | 111 |
| 2012 | 3 | 116.3 | 0.43 | 111 |
| 2012 | 4 | 87.1 | 0.36 | 126 |
| 2013 | 1 | 113.5 | 0.29 | 53 |
| 2013 | 2 | 152.6 | 0.30 | 124 |
| 2013 | 3 | 81.7 | 0.50 | 332 |
| 2013 | 4 | 82.4 | 0.32 | 135 |

**Table 2.** Continued.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **Mean Length**  **(cm, EFL)** | **CV of Length** | **Number of Fish Sampled** |
| 2014 | 1 | 101.0 | 0.34 | 58 |
| 2014 | 2 | 153.3 | 0.28 | 129 |
| 2014 | 3 | 109.7 | 0.46 | 171 |
| 2014 | 4 | 99.7 | 0.29 | 129 |
| 2015 | 1 | 110.4 | 0.32 | 76 |
| 2015 | 2 | 152.4 | 0.23 | 174 |
| 2015 | 3 | 108.1 | 0.38 | 151 |
| 2015 | 4 | 85.8 | 0.32 | 131 |
| 2016 | 1 | 113.4 | 0.33 | 134 |
| 2016 | 2 | 153.3 | 0.29 | 146 |
| 2016 | 3 | 98.7 | 0.46 | 150 |
| 2016 | 4 | 87.5 | 0.35 | 139 |
| 2017 | 1 | 124.6 | 0.33 | 91 |
| 2017 | 2 | 166.4 | 0.22 | 172 |
| 2017 | 3 | 90.1 | 0.47 | 163 |
| 2017 | 4 | 85.6 | 0.31 | 182 |
| 2018 | 1 | 109.5 | 0.34 | 130 |
| 2018 | 2 | 164.6 | 0.23 | 236 |
| 2018 | 3 | 96.6 | 0.47 | 120 |
| 2018 | 4 | 88.1 | 0.36 | 189 |
| 2019 | 1 | 116.3 | 0.31 | 66 |
| 2019 | 2 | 155.9 | 0.26 | 161 |
| 2019 | 3 | 107.8 | 0.50 | 115 |
| 2019 | 4 | 92.2 | 0.36 | 119 |
| 2020 | 1 | 150.6 | 0.26 | 93 |
| 2020 | 2 | 167.7 | 0.19 | 48 |
| 2020 | 3 | 89.4 | 0.51 | 105 |
| 2020 | 4 | 105.8 | 0.37 | 83 |
| 2021 | 1 | 139.0 | 0.36 | 58 |
| 2021 | 2 | 160.0 | 0.25 | 182 |
| 2021 | 3 | 114.6 | 0.41 | 113 |
| 2021 | 4 | 99.9 | 0.33 | 124 |
| 2022 | 1 | 142.8 | 0.34 | 72 |
| 2022 | 2 | 149.3 | 0.31 | 130 |
| 2022 | 3 | 115.7 | 0.44 | 99 |
| Average 1994-1999 | | 96.9 | 0.27 | 13 |
| Average 2000-2009 | | 108.1 | 0.35 | 192 |
| Average 2010-2019 | | 113.2 | 0.35 | 133 |
| Average 2020-2022 | | 130.4 | 0.34 | 101 |
| Average 1994-2022 | | 109.7 | 0.33 | 125 |

**Table 3.** Temporal associations as indexed by Pearson correlations between quarterly distributions of swordfish mean length (**mlen**), standard deviation of length (**stdlen**), mean weight (**mwt**), standard deviation of weight (**stdwt**) and the time index year-quarter (**yr.qtr**) for the **shallow-set sector (top)** and **deep-set sector (bottom)** of the Hawaii longline collected by the Pacific Islands Regional Observer Program during 1994-2022. Associations below the critical value at the 95% confidence level were judged to be weak and are italicized.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shallow-set sector** | | | | |
| **n=96** | **mlen** | **stdlen** | **mwt** | **stdwt** |
| **yr.qtr** | 0.41 | *0.21* | 0.48 | 0.40 |
| **mlen** |  | *-0.15* | 0.98 | 0.44 |
| **stdlen** |  |  | *0.00* | 0.74 |
| **mwt** |  |  |  | 0.57 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Deep-set sector** | | | | |
| **n=114** | **mlen** | **stdlen** | **mwt** | **stdwt** |
| **yr.qtr** | 0.30 | 0.39 | 0.30 | 0.47 |
| **mlen** |  | 0.58 | 0.98 | 0.84 |
| **stdlen** |  |  | 0.59 | 0.86 |
| **mwt** |  |  |  | 0.87 |

**Table 4.** Temporal associations as indexed by Pearson correlations between annual distributions of swordfish mean length (**mlen**), standard deviation of length (**stdlen**), mean weight (**mwt**), standard deviation of weight (**stdwt**) and the time index year (**yr**) for the **shallow-set sector (top)** and **deep-set sector (bottom)** of the Hawaii longline collected by the Pacific Islands Regional Observer Program during 1994-2022. Associations below the critical value at the 95% confidence level were judged to be weak and are italicized.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shallow-set sector** | | | | |
| **n=27** | **mlen** | **stdlen** | **mwt** | **stdwt** |
| **yr** | 0.70 | *0.34* | 0.71 | 0.63 |
| **mlen** |  | *0.31* | 0.99 | 0.71 |
| **stdlen** |  |  | 0.43 | 0.79 |
| **mwt** |  |  |  | 0.79 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Deep-set sector** | | | | |
| **n=27** | **mlen** | **stdlen** | **mwt** | **stdwt** |
| **yr** | 0.65 | 0.57 | 0.65 | 0.67 |
| **mlen** |  | 0.79 | 0.98 | 0.86 |
| **stdlen** |  |  | 0.82 | 0.93 |
| **mwt** |  |  |  | 0.91 |

**Figure 1.** Swordfish observed mean lengths (cm, EFL) by year and quarter for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



**Figure 2.** Swordfish calculated mean weights (kg) by year and quarter for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



**Figure 3.** Swordfish observed mean lengths (cm, EFL) by year with error bars showing ±2 standard errors of the mean length for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



**Figure 4.** Swordfish calculated mean weights (kg) by year with error bars showing ±2 standard errors of the mean weight for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



**Figure 5.** Swordfish observed mean lengths (cm, EFL) by quarter with error bars showing ±1 standard deviation of length for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



**Figure 6.** Swordfish calculated mean weights (kg) by quarter with error bars showing ±1 standard deviation of weight for the **shallow-set (a)** and **deep-set (b)** sectors of the Hawaii longline fishery during 1994-2022.

**(a) Shallow-set sector**



**(b) Deep-set sector**



# Appendixes

**Table A1.** Number of swordfish length observations (cm, eye-fork length) sampled by 5 cm length bins by year and quarter (35-270, 295 are 5 cm bins, with 275 and 285 are 10 cm bins) for the **shallow-set sector** of the Hawaii-based longline fishery.

**Table A1.** Continued.



**Table A1.** Continued.



**Table A1.** Continued.



**Table A1.** Continued.



**Table A1.** Continued.



**Table A2.** Number of swordfish length observations (cm, eye-fork length) sampled by 5 cm length bins by year and quarter (35-255, 275 are 5 cm bins, with 260 is a 15 cm bin) for the **deep-set sector** of the Hawaii-based longline fishery.



**Table A2.** Continued.



**Table A2.** Continued.



**Table A2.** Continued.

****

**Table A2.** Continued.

****

**Table A2.** Continued.

****

1. The average mean lengths of swordfish by sector calculated using a cutoff of 15 hooks per float to define sectors prior to 2005 were also equal to 146 and 110 cm for the shallow- and deep-set sectors, respectively. For the shallow-set sector, there were five quarters prior to 2005 where using a cutoff of 15 hooks per float to define sectors changed the mean length by 1% or more and the maximum percent change was 6% in quarter 4 of 1995. Similarly when using a cutoff of 15 hooks per float to define sectors, there were two quarters prior to 2005 where the mean length changed by 1% or more in the deep-set sector and the maximum percent change was 2% in quarter 4 of 1995. Overall, the sensitivity analysis showed that the application of a cutoff of 15 hooks per float to define sectors prior to 2005 had a negligible impact on the observed swordfish size composition data reported by quarter. [↑](#footnote-ref-1)
2. The correlation results for the quarterly and annual mean size distributions were the same using a cutoff of 15 hooks per float to define sectors prior to 2005. In particular, the pattern of strong positive associations reported in Tables 3 and 4 was replicated in the sensitivity analysis, noting that in this case, Spearman rank correlations were applied and similar results were achieved. [↑](#footnote-ref-2)