Assessment of the Flathead sole-Bering flounder Stock in the Bering Sea and Aleutian Islands

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# Executive Summary

“Flathead sole” as currently managed by the North Pacific Fishery Management Council (NPFMC) in the Bering Sea and Aleutian Islands (BSAI) represents a two-species complex consisting of true Flathead sole (*Hippoglossoides elassodon*) and its morphologically-similar congener Bering flounder (*Hippoglossoides spp.*). In 2012, the BSAI Groundfish Plan Team moved Flathead sole to a biennial stock assessment schedule because it has historically been lightly exploited. A full stock assessment report was most recently produced in 2020 (Monnahan and Haehn, 2020). A full assessment for BSAI flathead sole and BSAI skates were scheduled for 2022, but due to limited staff resources, a partial assessment is presented this year. In partial assessment years, an executive summary is presented to recommend harvest levels for the next two years, along with trends in catch and biomass.

Flathead sole is assessed using an age-structured model and Tier 3 determination. The single species projection model is run using parameter values from the accepted 2020 assessment model, together with updated catch information for 2020-2021 and estimated catches for 2022 and 2023-2024 (Figure 1), to predict stock status for Flathead sole in 2023-2024, and to make ABC recommendations for those years (Table 1).

## Summary of Changes in Assessment Inputs

This assessment used a single survey index of “total” *Hippoglossoides spp.* biomass that included the EBS “standard” survey areas and AI survey areas for the years 1982-2019 (Table 2). As was done in the 2020 full assessment (Monnohan et. al. 2020) and the 2021 partial assessment (Kapur 2021), we estimated a relationship between EBS shelf *Hippoglossoides spp.* survey biomass estimates and AI survey biomass estimates in years when no AI survey occurred. The estimation method uses the linear regression to find an AI biomass estimate in a particular year based on the EBS biomass estimate for that year. There was no AI survey conducted in 2021 and AI biomass was estimated with the linear equation (for plotting purposes). The 2022 total BSAI estimate was 710,804 t, a roughly 6% increase over the 2021 regression estimate of 670,091 t (Figure 2).

To run the projection model to predict ABCs for 2023 and 2024, we used true, updated catches for 2020 and 2021 and estimates for the total catches in 2022-2024. Note that the 2020 catch used in the last benchmark model was itself an estimate (8,555.53), about 9% less than the finalized observation used for projections here. The catch for 2022 (14,659 t) was estimated by adding the average catch between Oct 19 and December 31 over the years 2017-2021 to the 2022 catch as of Oct 19, 2022. The 2023 and 2024 catches (11,130 t) were estimated as the average catch over the previous 5 years (2017-2021).

To ensure consistency with the most recent full assessment (Monnohan et al., 2020), the projection model was parameterized using mean recruitment and stock spawning biomass for all years included in the assessment model (1964 onwards). Future full assessments for BS/AI Flathead sole can consider updating these inputs in light of the Oct 4, 1999 memorandum by R. Marasco indicating that projections of future stock states should be based on year classes 1977 and forward. Changing the projection inputs will affect the scale of the projected biomass, and result in discontinuities between assessment cycles.

## Summary of Results

Based on the updated projection model results, the recommended ABCs for 2023 and 2024 are listed in the table below. The ABC and OFL for 2023 are only slightly below those projected during the last partial assessment (2021), as finalized and estimated catches for 2021 and 2022 are higher than those used last year.

\*Projections are based on estimated catches of 14,659t used in place of maximum permissible ABC for 2022 and 11,130 t used in place of maximum permissible ABC for 2023-2024. The final catch for 2022 was estimated by taking the average tons caught between Oct 19 and December 31 over the previous 5 years (2017-2021) and adding this average amount to the catch-to-date as of Oct 19, 2022 which is shown at the bottom of Table 1. The 2023 and 2024 catch was estimated as the average of the total catch in each of the last 5 years.

| **Quantity** | As estimated or *specified last* year for: | | As estimated or *recommended this* year for: | |
| --- | --- | --- | --- | --- |
| 2022 | 2023 | 2023 | 2024 |
| *M* (natural mortality rate) | 0.2 | 0.2 | 0.2 | 0.2 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (3+) biomass (t) | 608,631 | 612,001 | 606,522 | 606,080 |
| Projected Female spawning biomass (t) | 155,379 | 160,748 | 158,962 | 164,594 |
| *B100%* | 203,658 | 203,658 | 203,658 | 203,658 |
| *B40%* | 81,463 | 81,463 | 81,463 | 81,463 |
| *B35%* | 71,280 | 71,280 | 71,280 | 71,280 |
| *FOFL* | 0.46 | 0.46 | 0.46 | 0.46 |
| *maxFABC* | 0.37 | 0.37 | 0.37 | 0.37 |
| *FABC* | 0.37 | 0.37 | 0.37 | 0.37 |
| OFL (t) | 77,967 | 80,034 | 79,256 | 81,167 |
| maxABC (t) | 64,288 | 65,988 | 65,344 | 66,927 |
| ABC (t) | 64,288 | 65,988 | 65,344 | 66,927 |
| **Status** | As determined last year for: | | As determined this year for: | |
| 2020 | 2021 | 2021 | 2022 |
| Overfishing | no | NA | no | NA |
| Overfished | NA | no | NA | no |
| Approaching Overfished | NA | no | NA | no |

# Tables

### Catch by Spp.

Table 1. Catch (in tons) of flathead sole and Bering flounder combined Hippoglossoides elassodon and Flathead sole only, and Hippoglossoides spp. only in the BSAI as of Oct 19, 2022 Observer data on species-specific extrapolated weight in each haul was summed over hauls within each year and used to calculate the proportion of the total Hippoglossoides spp. catch that was flathead sole or Bering flounder. Proportions were multiplied by the total Hippoglossoides spp. (flathead sole and Bering flounder combined) catches reported by AKFIN to obtain total catch of flathead sole separately from that of Bering flounder. 2022 catches are current as of Oct 19, 2022 and the value shown below does not include projections through the end of the year.

| Year | Total Hippoglossoides spp. | Flathead sole | Bering flounder |
| --- | --- | --- | --- |
| 1992 | 4 | 4 | 0 |
| 1995 | 14,715 | 14,710 | 4 |
| 1996 | 17,346 | 17,341 | 5 |
| 1997 | 20,683 | 20,678 | 5 |
| 1998 | 24,387 | 24,381 | 7 |
| 1999 | 18,573 | 18,553 | 20 |
| 2000 | 20,441 | 20,408 | 33 |
| 2001 | 17,811 | 17,795 | 16 |
| 2002 | 15,575 | 15,550 | 25 |
| 2003 | 13,785 | 13,767 | 18 |
| 2004 | 17,398 | 17,374 | 24 |
| 2005 | 16,108 | 16,077 | 31 |
| 2006 | 17,981 | 17,975 | 6 |
| 2007 | 18,958 | 18,952 | 6 |
| 2008 | 24,540 | 24,526 | 14 |
| 2009 | 19,558 | 19,530 | 28 |
| 2010 | 20,127 | 20,101 | 26 |
| 2011 | 13,557 | 13,536 | 20 |
| 2012 | 11,365 | 11,359 | 6 |
| 2013 | 17,353 | 17,272 | 80 |
| 2014 | 16,511 | 16,478 | 33 |
| 2015 | 11,306 | 11,273 | 33 |
| 2016 | 10,313 | 10,301 | 12 |
| 2017 | 9,111 | 9,107 | 3 |
| 2018 | 11,007 | 11,001 | 5 |
| 2019 | 15,880 | 15,879 | 1 |
| 2020 | 9,392 | 9,389 | 3 |
| 2021 | 10,259 | 10,255 | 4 |
| 2022 | 14,075 | 14,072 | 3 |

### Survey Biomass and CV (EBS/AI)

Table 2. Survey biomass in tons and coefficient of variation (CV) of Hippoglossoides spp. combined (flathead sole and Bering flounder) across the entire BSAI; flathead sole only in the Aleutian Islands, Hippoglossoides spp. combined in the Eastern Bering Sea (EBS) shelf survey, flathead sole only in EBS shelf survey, and Bering flounder only in the EBS shelf survey. Slight discrepancies in totals may occur due to rounding. Bolded years are not included in base model. Data accessed via Oracle database query on Oct 19, 2022.

| Year | Total | CV (Total) | Biomass (AI) | CV (AI) | Biomass (EBS, all) | CV (EBS, all) | Biomass (EBS, flathead) | CV (EBS, flathead) | Biomass (EBS, Bering Flounder) | CV (EBS, Bering Flounder) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1982 | 194,495 | 0.09 |  |  | 191,343 | 0.09 | 191,343 | 0.09 | 0 |  |
| 1983 | 271,475 | 0.10 | 1213 | 0.19 | 270,262 | 0.10 | 251,978 | 0.11 | 18,283 | 0.2 |
| 1984 | 289,521 | 0.08 |  |  | 284,782 | 0.08 | 269,777 | 0.09 | 15,005 | 0.21 |
| 1985 | 269,266 | 0.07 |  |  | 264,865 | 0.07 | 251,534 | 0.08 | 13,332 | 0.12 |
| 1986 | 362,170 | 0.09 | 5245 | 0.16 | 356,925 | 0.09 | 343,011 | 0.09 | 13,914 | 0.17 |
| 1987 | 399,227 | 0.09 |  |  | 392,657 | 0.09 | 378,525 | 0.10 | 14,132 | 0.14 |
| 1988 | 569,809 | 0.09 |  |  | 560,392 | 0.09 | 537,372 | 0.09 | 23,020 | 0.22 |
| 1989 | 528,394 | 0.08 |  |  | 519,668 | 0.08 | 500,932 | 0.09 | 18,737 | 0.2 |
| 1990 | 601,749 | 0.09 |  |  | 591,798 | 0.09 | 572,543 | 0.09 | 19,256 | 0.15 |
| 1991 | 552,288 | 0.08 | 6939 | 0.2 | 545,349 | 0.08 | 517,825 | 0.08 | 27,524 | 0.22 |
| 1992 | 626,811 | 0.10 |  |  | 616,443 | 0.10 | 601,311 | 0.11 | 15,131 | 0.21 |
| 1993 | 617,258 | 0.07 |  |  | 607,049 | 0.07 | 584,834 | 0.07 | 22,215 | 0.21 |
| 1994 | 699,446 | 0.07 | 9935 | 0.22 | 689,511 | 0.07 | 663,853 | 0.07 | 25,658 | 0.19 |
| 1995 | 603,875 | 0.09 |  |  | 593,889 | 0.09 | 578,457 | 0.09 | 15,432 | 0.18 |
| 1996 | 626,314 | 0.09 |  |  | 615,954 | 0.09 | 603,979 | 0.09 | 11,975 | 0.2 |
| 1997 | 794,426 | 0.21 | 11554 | 0.23 | 782,871 | 0.21 | 768,815 | 0.21 | 14,056 | 0.19 |
| 1998 | 693,723 | 0.20 |  |  | 682,237 | 0.20 | 674,412 | 0.20 | 7,825 | 0.21 |
| 1999 | 407,164 | 0.09 |  |  | 400,462 | 0.09 | 387,311 | 0.09 | 13,151 | 0.18 |
| 2000 | 401,106 | 0.09 | 8906 | 0.23 | 392,199 | 0.09 | 384,011 | 0.09 | 8,188 | 0.19 |
| 2001 | 522,844 | 0.10 |  |  | 514,211 | 0.10 | 502,853 | 0.11 | 11,358 | 0.21 |
| 2002 | 562,073 | 0.17 | 9898 | 0.24 | 552,175 | 0.18 | 547,271 | 0.18 | 4,904 | 0.19 |
| 2003 | 522,935 | 0.10 |  |  | 514,300 | 0.10 | 508,617 | 0.11 | 5,684 | 0.21 |
| 2004 | 624,805 | 0.08 | 13298 | 0.14 | 611,507 | 0.09 | 603,449 | 0.09 | 8,058 | 0.31 |
| 2005 | 622,249 | 0.08 |  |  | 611,956 | 0.09 | 604,878 | 0.09 | 7,078 | 0.28 |
| 2006 | 643,731 | 0.09 | 9664 | 0.17 | 634,067 | 0.09 | 620,215 | 0.09 | 13,852 | 0.31 |
| 2007 | 571,280 | 0.09 |  |  | 561,838 | 0.09 | 551,415 | 0.09 | 10,423 | 0.21 |
| 2008 | 553,591 | 0.14 |  |  | 544,445 | 0.14 | 534,364 | 0.14 | 10,080 | 0.19 |
| 2009 | 425,216 | 0.12 |  |  | 418,213 | 0.12 | 411,584 | 0.12 | 6,629 | 0.17 |
| 2010 | 506,197 | 0.14 | 11812 | 0.3 | 494,386 | 0.15 | 487,798 | 0.15 | 6,588 | 0.15 |
| 2011 | 593,351 | 0.18 |  |  | 583,540 | 0.18 | 576,761 | 0.19 | 6,779 | 0.15 |
| 2012 | 386,892 | 0.11 | 5566 | 0.15 | 381,326 | 0.12 | 374,716 | 0.12 | 6,610 | 0.14 |
| 2013 | 498,784 | 0.17 |  |  | 490,553 | 0.17 | 484,866 | 0.17 | 5,687 | 0.14 |
| 2014 | 532,889 | 0.13 | 13436 | 0.14 | 519,453 | 0.14 | 509,842 | 0.14 | 9,611 | 0.17 |
| 2015 | 399,247 | 0.11 |  |  | 392,677 | 0.11 | 381,696 | 0.12 | 10,981 | 0.17 |
| 2016 | 452,785 | 0.07 | 6759 | 0.15 | 446,026 | 0.07 | 433,243 | 0.07 | 12,783 | 0.23 |
| 2017 | 549,293 | 0.08 |  |  | 540,218 | 0.08 | 530,982 | 0.08 | 9,236 | 0.22 |
| 2018 | 494,579 | 0.08 | 6930 | 0.11 | 487,649 | 0.08 | 484,144 | 0.08 | 3,505 | 0.16 |
| 2019 | 604,109 | 0.14 |  |  | 594,119 | 0.14 | 592,039 | 0.14 | 2,080 | 0.32 |
| 2021 | 670,091 | 0.11 |  |  | 659,000 | 0.11 | 657,321 | 0.12 | 1,679 | 0.31 |
| 2022 | 710,804 | 0.18 | 10897 | 0.19 | 699,906 | 0.18 | 697,296 | 0.18 | 2,610 | 0.27 |

### Survey biomass and CV (NBS)

Table 3. Northern Bering Sea survey biomass (t) and coefficient of variation (CV) for flathead sole, Bering flounder, and the two combined (Hippoglossoides spp.). These data are not included in the base model and are presented here for reference only. Data accessed via Oracle database query on Oct 19, 2022.

| Year | Biomass (Total) | CV (Total) | Biomass (NBS, flathead) | CV (NBS, flathead) | Biomass (NBS, Bering Flounder) | CV (NBS, Bering Flounder) |
| --- | --- | --- | --- | --- | --- | --- |
| 2010 | 12,355 | 0.17 | 0 |  | 12,355 | 0.17 |
| 2017 | 19,882 | 0.21 | 79 | 0.65 | 19,804 | 0.21 |
| 2019 | 18,989 | 0.18 | 463 | 0.33 | 18,526 | 0.19 |
| 2021 | 8,523 | 0.21 | 138 | 0.78 | 8,384 | 0.22 |
| 2022 | 6,039 | 0.15 | 129 | 0.6 | 5,910 | 0.15 |

# Figures

### Catch vs. Total Biomass

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| --- |
| Figure 1. Catch to total biomass ratio using total biomass for age 3+ individuals for flathead sole in the Bering Sea and Aleutian Islands. Points include observed (closed points) or estimated (open points) catches for years 2020-2024, which are not present in the base model. |

### Survey Biomass (EBS/AI)

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| --- |
| Figure 2. Survey biomass from the EBS shelf and Aleutian Islands surveys for station depths less than or equal to 200 meters. Grey and blue points include true observations. A linear regression was used to estimate a relationship between EBS shelf Hippoglossoides spp. survey biomass estimates and AI survey biomass estimates in years when no AI survey occurred ( ‘x’ marks). Grey shading indicates ± 1 standard error. Blue points or ‘x’ marks indicate the survey biomass in 2021 and 2022, and are not included in the base assessment model. |

Author’s note: Changes have been made to the stratum-area table, which affects biomass and abundance estimates for EBS data (all years and species). In late 2022, Duane Stevenson (AFSC) provided the following communication about these changes. A visual comparison of EBS FHS survey values from a 2021 data pull vs. the values shown above indicated that the effect of the strata update was negligible. Future benchmark assessments for this species should update the entire survey time series, for consistency.

*Changes were made in 2021 to the stratum area table, which resulted in small changes to the biomass and abundance estimates for all survey years for all species. The changes that were made achieved the following objectives: The projection was transformed into a standard EPSG format; 200m contour was made contiguous to the BS slope shapefiles; EBS and NBS were made contiguous; The boundary artifact polygon was removed; Shapefiles exclude landmass using the ARDEM dataset (downloaded on 12/29/2017) at 0.0 elevation settings for ARDEM transformation/conversion not recorded. If depth limits are changed to 20m in the future, research into optimal settings is advised. NBS extent excludes station AA-10 which was dropped from sampling beginning in 2017. The southern border of the Chukchi Sea survey extent was altered for contiguity. These changes altered the area of extrapolation for each stratum from 0-1.9%, and increased the overall survey area (EBS + NBS) by 0.01%. Because we want to maintain consistency throughout the data series for trend analysis, these new stratum areas were applied to the entire data series this year.*

# References

Kapur, M.S. 2021. 9. Assessment of the Flathead Sole-Bering flounder Stock in the Bering Sea and Aleutian Islands. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510. Available [here](https://apps-afsc.fisheries.noaa.gov/refm/docs/2021/BSAIflathead.pdf).

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