22. Assessment of the Octopus Stock Complex in the Bering Sea and Aleutian Islands

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Executive Summary

Through 2010, octopuses were managed as part of the Bering Sea/Aleutian Islands (BSAI) "other species" complex, along with sharks, skates, and sculpins. Historically, catches of the other species complexes were well below TAC. Due to increasing market values, retention of species within the other species complex increased. Beginning in 2011, an amendment to the BSAI fisheries management plan provided separate management for sharks, skates, sculpins, and octopus and set catch limits for each species group. Initially, catch limits for octopus were set using Tier 6 methods based on the maximum historical incidental catch rate. Since 2012, a methodology based on consumption of octopus by Pacific cod (*Gadus macrocephalus*) has been used to set catch limits (see Conners *et al.* (2016) for methodological details).

This year's assessment is an operational update, meaning new consumption data was provided through 2023 to determine catch limits using the previous assessment's model/methodology. Alternative models/methodologies were not considered. At least eight species of octopus are found in the BSAI though in this update assessment, all octopus species are grouped into a single assemblage. The species composition of the octopus community is not well documented, but data indicate that the giant Pacific octopus (*Enteroctopus dofleini*) is the most common (Tables 22-1,-2,-3). Octopuses are taken as incidental catch in trawl, longline, and pot fisheries with a portion retained and sold for human consumption or bait. The BSAI trawl surveys produce highly variable biomass estimates for octopus (Figure 22-1).

Summary of Changes in Assessment Inputs

Changes in Input Data

1. The calculation of annual and long-term average consumption rates has been updated using 13,614 additional Pacific cod stomach samples collected from 2012-2013 and 2016-2023.

Changes in Assessment Methodology
There have been no changes to the assessment methodology

Summary of Results

For 2024, the recommended maximum allowable ABC from the Tier 6 specifications is 4,560 t. Reference values for octopus are summarized in the following table, with the recommended ABC and OFL values for 2024 in bold.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity/Status	2023	2024	**2024**	2025
Tier	6	6	6	6
OFL (t)	4,769	4,769	**6,080**	6,080
*max*ABC (t)	3,576	3,576	4,560	4,560
ABC (t)	3,576	3,576	**4,560**	4,560
	As determined *last* year for:		As determined *this* year for:	
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a

The BSAI octopus complex is not currently subject to overfishing because the 2022 catch, the most recent completed year, of 251 t is smaller than the 2022 OFL of 4,769 t.

Responses to SSC and Plan Team Comments on Assessments in General

There were no Plan Team or SSC comments specific to this assessment

Responses to SSC and Plan Team Comments Specific to this Assessment

There were no Plan Team or SSC comments specific to this assessment

Introduction

The full introduction can be found in the 2020 BSAI octopus assessment (Ormseth *et al.* 2020). What follows is an abbreviation of the 2020 introduction.

Octopuses are marine mollusks in the class Cephalopoda. The cephalopods, whose name literally means head foot, have their appendages attached to the head and include octopuses, squids, and nautiluses. The octopuses (order Octopoda) have only eight appendages/arms and, unlike other cephalopods, lack shells, pens, and tentacles. There are two groups of Octopoda, the cirrate and the incirrate. The cirrate have cirri (cilia-like strands on the suckers), possess paddle-shaped fins suitable for swimming in their pelagic and epibenthic ocean habitats (Boyle and Rodhouse 2005), and are much less common than the incirrate, which contain the more traditional forms of octopus. Octopuses are found in every ocean in the world and range in size from less than 20 cm to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini* (Wülker 1910). The most common octopus species observed in the Alaska Fishery Science

Center (AFSC) bottom trawl survey is *E. dofleini*, but there are at least seven other species found in the Bering Sea: *Sasakiopus salebrosus*, *Benthoctopus leioderma*, *Benthoctopus oregonensis*, *Graneledone boreopacifica*, *Opisthoteuthis californiana*, *Japetella diaphana* and *Vampyroteuthis infernalis*. These eight species represent seven genera and can be found from less than 10-m to greater than 1500-m depth. All but one, *J. diaphana*, are benthic octopuses. The mesopelagic *V. infernalis* is a cephalopod that shares similarities with both octopuses and squids, but is included in the octopus assessment. The state of knowledge of octopuses in the BSAI, including the true species composition, is very limited.

Fishery

A full description of the fishery's history can be found in the 2020 BSAI octopus assessment (Ormseth *et al.* 2020). What follows are any recent significant changes to the fishery or management measures.

Directed Fishery

There is no federally-managed directed fishery for octopus in the BSAI. The State of Alaska allows for directed (under a special commissioner's permit) and incidental catch of octopus in state waters. Since 2006, the number of permits for direct octopus fishing has been declining. The catch of octopus in state waters has been predominately incidental (Bevaart 2022; Nichols and Shaishnikoff 2022).

Incidental Catch

Octopus are caught incidentally throughout the BSAI in both state and federally-managed bottom trawl, longline, and pot fisheries. Since 2003, the total octopus catch in federal waters (including discards) has been estimated using the National Marine Fisheries Service (NMFS) Alaska Regional Office catch accounting system. Total incidental catch range from approximately 200-700 t with high year-to year variability (Table 22-4). In 2011, the catch for octopus in BSAI (577 t) exceeded the OFL (528 t) resulting in NMFS closing the directed fishing for Pacific cod with pot gear in the BSAI on October 21, 2011. The following year, an alternative Tier 6 method for determining harvest levels was introduced. Since then, all catches have been nearly an order of magnitude below the recommended ABC (Table 22-4).

Data

Fishery

Catch

See Table 22-4 and Figure 22-2 for a time series of the total catch from 1997 to 2023. The 2023 catch data are incomplete. They were updated through September 16, 2023.

Survey

AFSC Trawl Survey Biomass Estimate

Bottom trawl surveys were conducted on an annual basis in the Eastern Bering Sea (EBS) shelf and biennially in the Aleutian Islands (AI) beginning in 2000. Both of these surveys were canceled in 2020 due to the COVID-19 pandemic. The EBS slope surveys were conducted irregularly and was last sampled in 2016. Estimated biomass for the octopus stock complex based on the AFSC bottom trawl surveys are shown in Tables 22-1,-2 and -3. Biomass estimates in the EBS and AI show high year-to-year variability (Figure 22-1). There is a large sampling variance associated with estimates from the shelf surveys because

a large number of tows do not capture octopuses. It is impossible to determine how much of the year–to-year variability in the estimated biomass reflects true variation in abundance or is a result of sampling variation. For example, the 1997 biomass estimate from the shelf survey (254 t) approximately equaled the estimated commercial catch (249 t). This suggests that the 1997 biomass estimate was unreasonably low. The 2023 EBS biomass estimate (2,557 t) is a decrease of 48% from 2022 (4,941 t). The 2023 EBS biomass estimate is also 39% lower than the long-term average biomass estimate (4,189 t) and is the lowest biomass estimate since 2014.

Other Data

The BSAI octopus assessment utilizes diet data from Pacific cod, the main predator of Octopus in the BSAI. These data area available from the AFSC food habits group (Table 22-5). A total of 13,614 stomachs from 2012-2013 and 2016-2023 have been added to the data set since the last assessment update in 2016.

Analytical approach

General Model Structure

The available data for octopus in the BSAI do not support quantitative catch-at-age modeling for either individual species of octopus or for the multi-species complex. There are also no reliable biomass estimates available for Tier 5 methods. Therefore, we continue to use the alternative Tier 6 method, based on a predation-based estimate of total natural mortality (*N*) (Conners *et al.* 2011). We use the letter *N* for the total natural mortality in tons to distinguish it from the *M* (continuous individual mortality rate) that is used widely in other stock assessment models (Ormseth *et al.* 2020).

This alternative Tier 6 method utilizes diet data from the AFSC's food habits database to estimate the total amount of octopus consumed by their main predator in the BSAI: Pacific cod. The estimated amount of octopus consumed by Pacific cod is thought to be a conservative estimate of the total natural mortality *N* for octopus, since it does not include mortality from other predators (i.e., marine mammals) or non-predation mortality. It is important to note that this methodology calculates a single reference point that is averaged over multiple years in order to avoid assuming a population increase when it is just an increase in predation. Therefore, the reference point should be periodically updated but not annually. This analysis was first performed in 2011 (Conners *et al.* 2011) and last updated in the 2016 assessment (Conners *et al.* 2016).

Parameter Estimates

Total Natural Mortality (N)
N was estimated using previously defined methods. The annual geometric mean values of *N* can be found in Table 22-6. The OFL equals geometric mean of the annual values. See "General Model Structure" for a description and the 2016 BSAI octopus assessment (Conners *et al.* 2016) for more details.

Results

Harvest Recommendations

Amendment 56 Reference Points
In previous assessments, catch limits for the octopus stock complex were set using Tier 6 methods based on the maximum historical incidental catch rate. Beginning in 2012, an alternative Tier 6 method based

on predation-based estimate of total natural mortality (*N*) was adopted that is based on biological reference points derived from octopus consumption estimates from Pacific cod. This estimate of natural mortality (*N*) can then be combined with the general logistic fisheries model that forms the basis of Tier 5 assessments (Alverson and Pereyra 1969; Francis 1974) (Alverson and Petreyra 1969, Francis 1974). Thus, the overfishing limit is set equal to *N*, and the recommended maximum permissible ABC for the octopus stock complex is defined to occur at a harvest rate of 0.75 * OFL. to set OFL = *N* and ABC = 0.75 * OFL.

Specification of OFL and Maximum Permissible ABC
Using the modified Tier 6 methodology, the resulting catch limits are OFL = 6,080 t and ABC = 4,560 t which are our recommended 2024 and 2025 ABCs and OFLs.

We do not recommend a directed fishery for octopus in federal waters at this time, because data are insufficient for adequate management. We anticipate that octopus catch in federal waters of the BSAI will continue to be largely incidental catch in existing groundfish fisheries.

Status Determination
The BSAI octopus complex is not currently subject to overfishing because the 2022 catch, the most recent completed year, of 251 t is smaller than the 2022 OFL of 4,769 t (Figure 22-2).

Risk Table and ABC recommendation

The following template is used to complete the risk table:

	Assessment-related considerations	***Population dynamics considerations***	***Environmental/ecosystem considerations***	***Fishery Performance***
Level 1: No Conern	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 3: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance.

Assessment-related considerations: The octopus complex is a Tier 6 stock and thus by definition data-limited; many potential concerns such as the lack of reliable abundance data are inherent to Tier 6 stocks and harvest recommendations are made accordingly. There are no additional considerations that would warrant reducing the ABC below maximum permissible. Rated Level 1, normal.

Population dynamics considerations: For a data-limited stock such considerations are hard to evaluate. In addition octopuses are short-lived and signals like recruitment are harder to discern. However, the results from this years operational updated have an increased OFL and ABC from the previous year. Rated Level 1, normal.

Environmental/ecosystem considerations: Very little is understood about mechanistic linkages between ecosystem drivers and octopus growth, survival, or stock dynamics. Octopus are fast-growing animals. Sano and Bando (2018) studied the giant Pacific octopus (*Enteroctopus dolfeini*) in captivity and found both growth and feeding rates have a dome shaped relationship with temperature where maximum growth rates have been observed around 10°C and maximum feeding rates between 10-15°C; activity also tends to increase with temperature. Limited knowledge of these species exists to identify stock-specific indicators. Peak spawning occurs in winter to early spring, hatch time varies between 150 days to one year and the paralarvae period of ~90 days occurs around June- Aug (Conrath and Conners 2014). Based on 1993-2022 bycatch records (North Pacific Observers groundfish data, https://apps-afsc.fisheries.noaa.gov/ords/r/fma_ols/fma-map/) and frequency of occurrence in non-empty Pacific cod stomachs from 1981-2011 (Rohan and Buckley 2017) show octopus are distributed along the outer and middle domain, and the Aleutian Islands. Spencer *et al.* (2019) assessed the climate vulnerability of Pacific giant octopus based on traits and expert evaluation, and found the sensitivity, exposure and vulnerability to be low when rubrics were scored moderate only if 2 or more individual attributes had mean values ≥ 2.5. However, when an alternative logic rule was used (less than 2 attributes with mean value ≥ 2.5 and more than ≥2 attributes with mean value ≥ 1.5), then the ranking increased to moderate for sensitivity, exposure and vulnerability.

Environmental processes: In 2023, broad-scale climate patterns, like the North Pacific Index, reflected a transition from La Niña conditions to developing El Niño conditions in the tropic Pacific. In the eastern Bering Sea, regional sea surface temperature trends were at or near the long-term average in 2023. Exceptions to near-normal sea surface temperature (SST) conditions include a relatively warm winter across the shelf. Above-average SSTs lasted through spring over the outer (100-200m isobaths) and middle (50-100m isobaths) domains. Bottom temperatures derived from the ROMS model showed consistently cooler than average bottom temperatures over the outer domain (100-200m) from September 2022 through August 2023. Sea ice metrics, such as early ice extent (Oct. - Dec.), annual ice extent, and sea ice thickness were all near the respective time series averages. The 2023 cold pool extent was also near its historical average (Hennon *et al.* 2023). Data from the 2023 EBS bottom trawl survey (AFSC 2023) show bottom temperatures below 6°C in the outer and middle domain. Likewise, bottom temperatures in the AI from 1994-2022 show mean bottom temperatures across the chain below 6°C. Temperatures from the longline survey show temperature between 100 - 300 m was also below 6°C in the eastern Aleutians (Siwicke 2023). The trend of increasing temperatures in the AI favors faster growth rates and increased feeding rates. Within the EBS shelf, overall octopus biomass seems to be inversely related to cold pool areas, however it is unclear whether the changes in biomass are driven by population increase or movement of octopus (e.g. from the slope to the shelf).

Prey: Prey for octopus includes shrimps, crabs, and benthic infauna (e.g., clams). No direct measures for shrimps are available from the eastern Bering Sea or Aleutian Islands. In the eastern Bering Sea, biomass trends for several crab stocks have declined in recent years and are currently below their respective time series averages (Richar 2023). Indirect measures of benthic infauna availability based on biomass trends of benthic foragers indicates reduced infaunal prey available (Siddon 2023). Available information on prey resources for octopus is difficult to directly assess; some indicators of prey conditions appear low in 2023, though mechanistic linkages to octopus stock dynamics remain elusive. There is no prey information for the AI at this time.

Competitors: Competitors of adult or large octopus include Pacific halibut and Pacific cod among others. The Pacific halibut stock decreased from a peak in the early 2000s and remains low in 2023, therefore represents no increase in competitor pressure (Stewart and Hicks 2022). In the EBS Pacific cod had a modest increase in biomass from 2022 to 2023, but also does not represent a substantial increase in competitor pressure. In the AI, total biomass of Pacific cod has been steadily decreasing with biomass in 2022 at ~25% of its peak biomass in 1989 (Spies *et al.* 2022).

Predators: Predators of octopus include Pacific cod, fur seals, Steller sea lions, and seabirds. Pacific cod had a modest increase in biomass from 2022 to 2023, while fish condition (based on length-weight residuals) over the outer shelf was below average in 2023 (Prohaska and Rohan 2023). Fur seal population trends at St. Paul Island continued a declining trend through 2022 (Siddon 2023). Seabird populations at the Pribilof Islands showed mixed trends for 2023 with higher reproductive success at St. George compared to St. Paul Island (Siddon 2023). Additional occasional predators of octopus in the Aleutian Islands include Pacific halibut and Atka mackerel as well as Pacific cod and Steller sea lions [Ormseth *et al.* (2020); Fritz *et al.* (2019)). Steller sea lion populations in the western and central Aleutian Islands continued a declining trend (Sweeney and Gellat 2022) and Atka mackerel decreased slightly in 2022 to around 561,000 tons and is down from almost peak abundances in 2003-04 of 1 million tons. Overall predation on octopus in the Aleutians is expected to be lower than in past years.

Summary for Environmental/Ecosystem considerations:

- **Environment**: Oceanographic metrics for the EBS showed average conditions over the past year (August 2022 - August 2023). In the Aleutian Islands midwater temperatures remained below 6°C (summer 2023) in the Eastern AI, as have mean bottom summer temperatures across the chain.
- **Prey**: In the EBS, some indicators of prey conditions appear low in 2023, though mechanistic linkages to octopus stock dynamics remain elusive. No information in the AI.
- **Competitors**: Trends in available information for competitors of octopus suggest no increase in competitor pressure in 2023 in the EBS and decreasing trends in the AI (of known competitors)
- **Predators**: Trends in available information for predators of octopus suggest no increase in predation pressure in 2023 for the EBS and decreasing trends in the AI

Proper evaluation of risk is difficult for a data-limited stock. However, the available data suggest there are no apparent ecosystem concerns–Level 1.

Fishery performance: As a nontarget stock, catches of octopuses in the GOA are influenced by their abundance and by the behavior of target fisheries. The catches have remained low, with the majority of the catch occurring as bycatch in the Pacific cod fishery. Rated Level 1, normal.

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: No increased concerns	Level 1: No increased concerns	Level 1: No increased concerns	Level 1: No increased concerns

The score of level 1 for each category suggests that setting the ABC below the maximum permissible is not warranted at this time.

Ecosystem Considerations

A full description of the ecosystem considerations can be found in the 2020 BSAI octopus assessment (Ormseth *et al.* 2020). There is also thorough ecological description in the **Risk Table and ABC recommendation** segment under the **Results** section. What follows is an abbreviation from the 2020 BSAI octopus assessment of information not included in the **Results** section.

The majority of the octopus incidental catch is taken in pot gear fished for Pacific cod. To avoid gear conflicts with trawlers, cod pots are usually deployed inside of no-trawl zones or in rocky areas unsuitable for trawling. The low retention rate of octopus in the BSAI, and the high survival rate of discarded octopus suggest that effects on the octopus population is minor.

Data Gaps and Research Priorities

A full description of the data gaps and research priorities can be found in the 2020 BSAI octopus assessment (Ormseth *et al.* 2020). What follows is an abbreviation from the 2020 BSAI octopus assessment.

Though there have been efforts to improve the collection of basic octopus data, there is still a lot that is unknown. The areas of needed/ongoing research include improving aging methods, determining octopus species composition in catch and survey, determining octopus distribution especially when reproducing and producing reliable fisheries independent biomass estimates.

References

Alverson, D.L. and Pereyra, W.T. (1969) Demersal fish explorations in the northeastern Pacific ocean – an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. *Journal of the Fisheries Research Board of Canada* 26, 1985–2001.

Bevaart, K. (2022) Annual management report for shellfish fisheries in the Kodiak, Chignik, and South Peninsula Districts, 2021. Alaska Department of Fish; Game, Fishery Management Report No. 22-18, Anchorage.

Boyle, P. and Rodhouse, P. (2005) *Cephalopods: Ecology and Fisheries*. Blackwell Publishing, Oxford, UK.

Conners, M.E., Aydin, K.Y. and Conrath, C.L. (2016) Assessment of the octopus stock complex in the Bering Sea and Aleutian Islands. In: *Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands regions*. North Pacific Fishery Management Council, Anchorage, AK.

Conners, M.E., Conrath, C.L. and Aydin, K. (2011) Assessment of the octopus stock complex in the Bering Sea and Aleutian Islands. In: *Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands regions*. North Pacific Fishery Management Council, Anchorage, AK.

Conrath, C.A. and Conners, M.E. (2014) Aspects of the reproductive biology of the giant Pacific octopus (*Enteroctopus dofleini*) in the Gulf of Alaska. *Fishery Bulletin, U.S.* 112, 253–260.

Francis, R.C. (1974) Relationship of fishing mortality to natural mortality at the level of maximum sustainable yield under the logistic stock production model. *Journal of the Fisheries Research Board of Canada* 31, 1539–1542.

Fritz, L., Brost, B., Laman, E., et al. (2019) A re-examination of the relationship between Steller sea lion (*Eumetopias jubatus*) diet and population trend using data from the Aleutian Islands. *Canadian Journal of Zoology* 97, 1137–1155.

Hennon, T., Barnett, L., Bond, N., et al. (2023) Physical Environment Synthesis. In: *Ecosystem Status Report 2023: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Nichols, E. and Shaishnikoff, J. (2022) Annual management report for shellfish fisheries of the Bering Sea/Aleutian Islands Management Area, 2021/22. Alaska Department of Fish; Game, Fishery Management Report No. 22-28, Anchorage.

Ormseth, O.A., Conners, E.M., Aydin, K. and Conrath, C.L. (2020) Assessment of the octopus stock complex in the Bering Sea and Aleutian Islands. In: *Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands regions*. North Pacific Fishery Management Council, Anchorage, AK.

Prohaska, B. and Rohan, S. (2023) Eastern and Northern Bering Sea Groundfish. In: *Ecosystem Status Report 2023: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Richar, J. (2023) Eastern Bering Sea Commercial Crab Stock Biomass Indices. In: *Ecosystem Status Report 2023: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Rohan, S.K. and Buckley, T.W. (2017) Spatial and ontogenetic patterns of Pacific cod (*Gadus macrocephalus Tilesius*) predation on octopus in the eastern Bering Sea. *Environmental Biology of Fishes* 100, 361–373.

Sano, M. and Bando, T. (2018) Effect of temperature on growth, feeding and food conversion rates of immature North Pacific giant octopus *Enteroctopus dofleini* in captivity. *NIPPON SUISAN GAKKAISHI* 84, 65–69.

Siddon, E.C. (2023) Eastern Bering Sea 2023 Report Card. In: *Ecosystem Status Report 2023: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Siwicke, K. (2023) Mid water temperature - longline survey. In: *Ecosystem Status Report 2023: Aleutian Islands, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Spencer, P.D., Hollowed, A.B., Sigler, M.F., Hermann, A.J. and Nelson, M.W. (2019) Trait-based climate vulnerability assessments in data-rich systems: An application to eastern bering sea fish and invertebrate stocks. *Global Change Biology* 25, 3954–3971.

Spies, I., Barbeaux, S., Hulson, P., Lman, N. and Ortiz, I. (2022) Assessment of the Pacific cod stock in the Aleutian Islands. In: *Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands regions*. North Pacific Fishery Management Council, Anchorage, AK.

Stewart, I. and Hicks, A. (2022) Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2021. International Pacific Halibut Commission, IPHC-2022-SA-01.

Sweeney, K. and Gellat, T. (2022) Steller Sea Lions in the Aleutian Islands. In: *Ecosystem Status Report 2022: Aleutian Islands, Stock Assessment and Fishery Evaluation Report*. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Wülker, G. (1910) Uber Japanische cephalopoden: Beitrage zur kenntnis der systematik und anatomie der dibranchiaten. *Abhandlungen der Mathematisch-Physikalischen Classe der Koniglich Bayerischen Akademie der Wissenschaften* 1, 1–77.

Tables

Table 22-1. AFSC Aleutian Islands trawl survey biomass estimates (t) for octopus species. CV is coefficient of variation. "Other Octopus" include *B. leioderma, J. diaphana, S. salebrosus, B. oregonensis* and octopus unidentified.

	E. dofleini		Other Octopus		Total	
Year	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**
1991	57	45	1,102	21	1,159	20
1994	1,186	27	541	21	1,727	19
1997	451	50	769	27	1,219	25
2000	444	45	345	38	788	30
2002	623	25	769	47	1,393	28
2004	4,076	35	20	98	4,095	34
2006	3,037	17	25	69	3,062	17
2010	3,074	30	1	55	3,075	30
2012	2,739	42	41	52	2,779	42
2014	2,762	20	83	21	2,845	20
2016	3,752	24	81	93	3,833	24
2018	2,231	40	44	87	2,274	39
2022	1,505	23	0	72	1,505	23

Table 22-2. AFSC EBS shelf trawl survey biomass estimates (t) for octopus species. CV is coefficient of variation. "Other Octopus" include *B. leioderma, S. salebrosus, B. oregonensis* and octopus unidentified.

	E. dofleini		Other Octopus		Total	
Year	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**
1987	4,181	88	3,648	47	7,829	52
1988	5,921	42	3,944	37	9,865	29
1989			4,895	33	4,895	33
1990			11,589	48	11,589	48
1991			8,070	34	8,070	34
1992			5,607	42	5,607	42
1993			1,582	34	1,582	34
1994			2,480	39	2,480	39
1995			2,934	59	2,934	59
1996			1,809	68	1,809	68
1997			254	40	254	40
1998	548	100	738	49	1,285	51
1999			834	52	834	52
2000	465	100	1,563	44	2,028	41
2001	100	69	5,785	32	5,885	32
2002	641	95	1,860	49	2,502	44
2003	5,163	65	3,091	58	8,254	46
2004	4,919	31	35	86	4,954	31
2005	9,558	30	657	48	10,215	28
2006	1,570	40	334	44	1,904	34
2007	2,113	31	163	45	2,276	29
2008	1,013	48	157	62	1,170	42
2009	819	64	195	53	1,013	53
2010	642	59	169	50	811	48
2011	2,833	33	708	66	3,541	30
2012	2,088	39	478	37	2,566	32
2013	1,657	53	156	41	1,813	49
2014	2,078	54	256	52	2,334	49
2015	5,223	31	115	62	5,338	30
2016	6,927	47	515	28	7,442	44
2017	1,777	44	2,240	27	4,017	24
2018	4,648	29	603	37	5,251	26
2019	5,538	26	378	38	5,916	24
2021	5,026	31	28	67	5,054	31
2022	4,628	28	313	71	4,941	26
2023	2,518	32	39	38	2,557	32

Table 22-3. AFSC EBS slope trawl survey biomass estimates (t) for octopus species. CV is coefficient of variation. "Other Octopus" include *B. leioderma, G. boreopacifica, J. diaphana, S. salebrosus, B. oregonensis, O. californiana* and octopus unidentified.

	E. dofleini		Other Octopus		Total	
Year	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**
2002	410	39	560	12	971	18
2004	993	24	987	15	1,980	14
2008	336	33	445	15	781	17
2010	216	33	405	15	621	15
2012	647	43	771	15	1,419	21
2016	566	31	1,697	14	2,263	13

Table 22-4. Estimated catch (t) of all octopus species from 1997-2023 in the Bering Sea and Aleutian Islands, by target fishery. Data reflect catch posted through September 16, 2023 (sourced October 17, 2023 from the NMFS Alaska Regional Office using the AKFIN database (http://www.akfin.org)). Catch is divided into three groups based on the target fishery; Pacific cod (typically highest octopus catch), all species of flatfish and all other target fisheries combined. Pacific halibut are included in the 'other' category. Octopus did not have their own catch limits until 2011. An alternative Tier 6 method was adopted in 2012.

	Target Fishery								
Year	**P.cod**	**Flatfish**	**Other**	**Total**	**Retained**	**OFL**	**ABC**	**TAC**	**Catch/ABC**
1997	160	86	3	249					
1998	168	13	9	190					
1999	310	14	2	326					
2000	359	57	3	419					
2001	211	9	7	227					
2002	334	21	19	374					
2003	224	32	21	277	31%				
2004	278	44	246	569	55%				
2005	311	17	10	339	64%				
2006	331	5	14	350	55%				
2007	156	7	9	171	41%				
2008	196	11	8	215	36%				
2009	58	10	6	73	22%				
2010	168	12	5	185	29%				
2011	555	9	14	577	6%	528	396	150	146%
2012	126	4	8	137	17%	4,769	3,576	900	4%
2013	214	2	4	220	22%	4,769	3,576	500	6%
2014	406	5	18	429	20%	4,769	3,576	225	12%
2015	412	6	24	441	18%	4,769	3,576	400	12%
2016	554	5	34	593	16%	4,769	3,576	400	17%
2017	264	4	13	282	31%	4,769	3,576	400	8%
2018	262	4	23	290	59%	4,769	3,576	250	8%
2019	238	13	17	268	48%	4,769	3,576	400	7%
2020	672	3	16	691	21%	4,769	3,576	275	19%
2021	154	8	8	170	13%	4,769	3,576	700	5%
2022	222	8	21	251	29%	4,769	3,576	700	7%
2023*	81	5	35	120	49%	4,769	3,576	400	3%

*2023 catch as of September 16, 2023 , sourced October 17, 2023 from the NMFS Alaska Regional Office using the AKFIN database (http://www.akfin.org).

Table 22-5. Number of Pacific cod stomach samples, from 1984-2023, analyzed for octopus consumption estimates. A total of 52,843 stomachs were analyzed.

Year	# of Samples	Year	# of Samples
1984	581	2004	0
1985	793	2005	449
1986	1,351	2006	705
1987	790	2007	583
1988	573	2008	1,208
1989	1,678	2009	1,345
1990	1,157	2010	1,198
1991	1,597	2011	1,550
1992	1,903	2012	1,838
1993	2,317	2013	1,657
1994	2,397	2014	1,644
1995	2,420	2015	1,942
1996	1,336	2016	1,954
1997	1,165	2017	1,611
1998	1,272	2018	1,619
1999	1,313	2019	1,246
2000	1,405	2020	0
2001	1,428	2021	1,565
2002	1,333	2022	985
2003	1,796	2023	1,139

Table 22-6. The annual geometric mean value from the posterior distribution for the estimated consumptions of octopus by Bering Sea Pacific Cod. L95% and U95% are the lower and upper portions of the 95% confidence interval.

Year	Mean	L95%	U95%
1984	5,311	1,066	22,726
1985	6,907	2,191	18,468
1986	4,318	2,259	7,984
1987	8,386	2,645	24,836
1988	316	22	1,908
1989	6,340	2,240	14,852
1990	1,585	322	6,897
1991	2,373	1,045	5,159
1992	354	147	782
1993	6,721	3,289	12,508
1994	4,717	2,027	11,675
1995	3,216	1,694	5,862
1996	3,982	1,756	8,617
1997	4,456	2,228	8,259
1998	4,227	1,439	10,571
1999	4,383	1,804	10,128
2000	6,185	2,458	14,257
2001	11,700	4,129	28,311
2002	3,027	1,513	5,824
2003	3,838	2,092	6,592
2005	18,336	7,607	39,602
2006	12,002	4,457	26,180
2007	20,370	5,501	53,015
2008	2,021	641	6,071
2009	1,578	445	4,826
2010	8,935	3,244	21,621
2011	21,958	13,246	35,808
2012	6,356	3,703	10,436
2013	10,069	6,046	16,013
2014	15,738	9,764	24,876
2015	17,980	11,479	28,046
2016	27,124	18,153	39,375
2017	24,813	14,153	39,978
2018	16,931	10,482	26,424
2019	13,849	7,487	23,673
2021	13,981	6,297	26,674
2022	5,815	2,797	11,633
2023	9,437	3,960	21,267

Figures

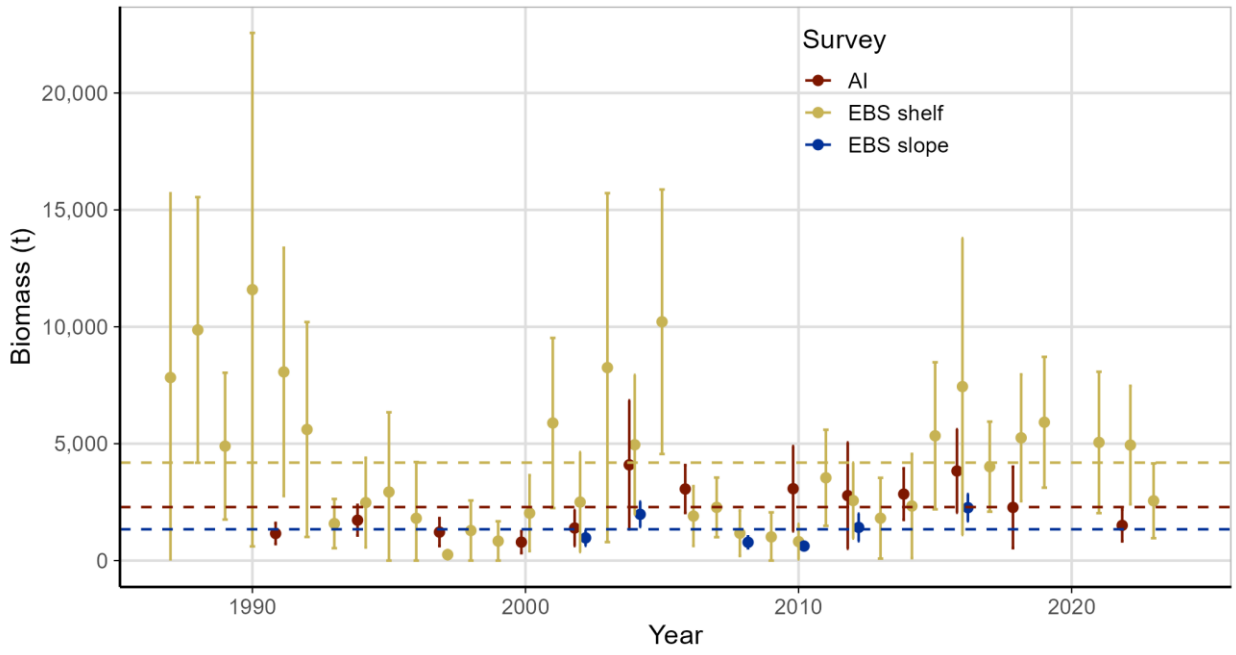

Figure 22-1. Octopus biomass estimates from the Eastern Bering Sea (EBS) shelf (1987-2023), EBS slope (2002-2016) and Aleutian Islands (AI) (1991-2022) surveys. The horizontal dashed lines represent the long-term average biomass for the survey with the same color. The long-term average for the AI is 2,289 t, the EBS shelf is 4,189 t and the EBS slope is 1,339 t.

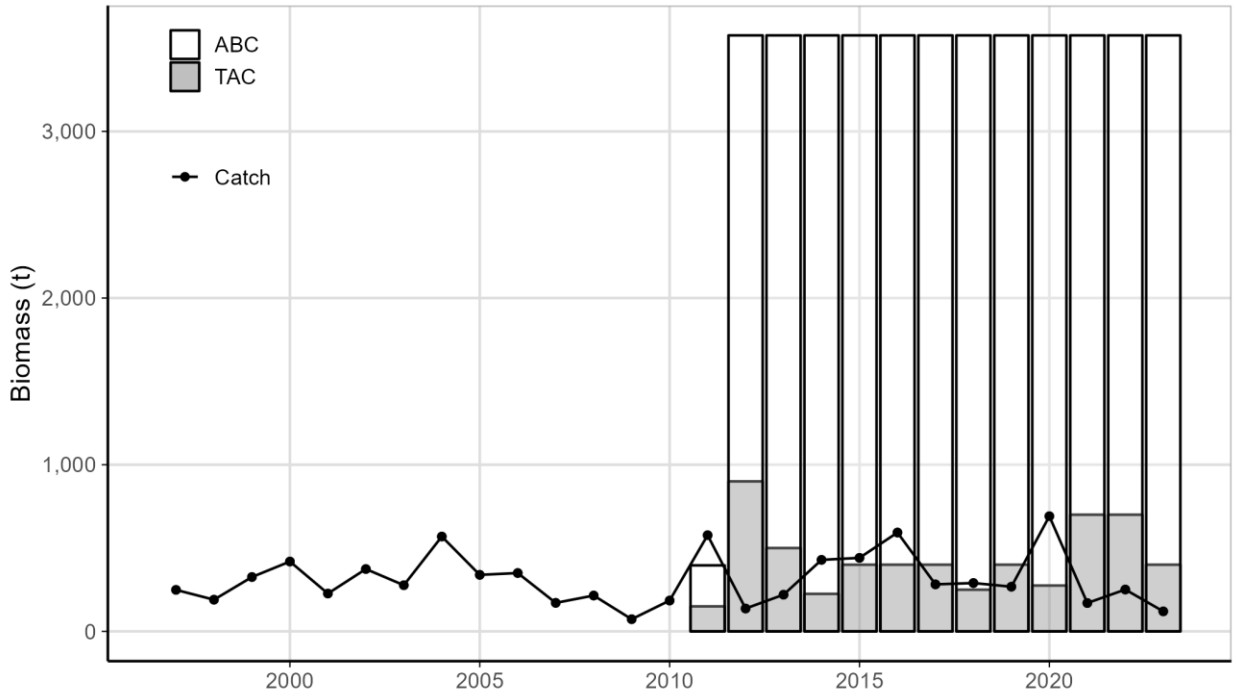

Figure 22-2. Octopus catch (retained and discarded), ABC and TAC from 1997-2023. Data reflect catch posted through September 16, 2023 (sourced October 17, 2023 from the NMFS Alaska Regional Office using the AKFIN database (http://www.akfin.org)).