

22. Assessment of the Octopus Stock 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 was 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 has been used to set catch limits.

This year will be an update assessment. This means new data, i.e. consumption data, was added to the model/methodology from the previous assessment to determine a new overfishing limit (OFL) and acceptable biological catch (ABC). Alternative models/methodologies were not considered.

In this update assessment, all octopus species are grouped into one assemblage. At least nine species of octopus are found in the BSAI. 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 in shelf waters and commercial catch. 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. Unfortunately, there is no reliable estimate of octopus biomass even though the state of knowledge about BSAI octopus is increasing.

Summary of Changes in Assessment Inputs

- 1) This assessment methodology has not changed from previous assessments, but the calculation of annual and long-term average consumption rates has been updated using 13,614 additional Pacific cod stomach samples collected from 2012-2023. The updated data set and estimates were used to derive updated catch limits. The detailed methodology for these calculations can be found in the 2016 assessment (Connors *et al.* 2016).
- 2) Incidental catch data have been updated through September 16, 2023.
- 3) Biomass estimates from the *Years* EBS shelf trawl surveys, and the *Years* Aleutian Islands trawl survey are presented. The last BS slope survey was conducted in 2016.

Summary of Results

List of changes (if any) in the input data, including estimated catches assumed for the current year and projected catches for current year + 1 and current year + 2. List of changes (if any) in the assessment methodology. This is one of the most important sections of the SAFE report. Common mistakes in this section include: 1) listing something that has not changed, and 2) not listing something that has changed.

Quantity/Status	As estimated or <i>specified last year</i> for:		As estimated or <i>recommended this</i> year for:	
	2023	2024	2024	2025
Tier	2023	2023	2023	2023
OFL (t)	4,769	4,769	6,080	6,080
<i>max</i> ABC (t)	3,576	3,576	4,560	4,560
ABC (t)	3,576	3,576	4,560	4,560
Status	As determined <i>last</i> year for:		As determined <i>this</i> year for:	
	2022	2023	2023	2024
Overfishing	n/a	n/a	n/a	n/a

Responses to SSC and Plan Team Comments on Assessments in General

“The SSC requests that all authors fill out the risk table in 2019...” (SSC December 2018)

A risk table has been included in this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

“For this cycle, the SSC also agrees with the author’s justification for the adjustment of the likelihood weight of the survey index to utilize this new time series more appropriately.”

The likelihood weighting has remained consistent with the weights found in the last full assessment.

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 nautilus. The octopuses (order Octopoda) have only eight appendages or arms, and unlike other cephalopods, they 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 deep ocean pelagic and epibenthic 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 (total length) to over 3 m (total length); the latter is a record held by *Enteroctopus dofleini* (Wülker 1910). *E. dofleini* is one of at least nine species of octopus

found in the Bering Sea, including one newly identified species. Members of these nine species represent seven genera and can be found from less than 10-m to greater than 1500-m depth. All but one, *Japetella diaphana*, are benthic octopuses. The mesopelagic *Vampyroteuthis 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

The full description of the history fishery can be found in the 2021 skate assessment (Olav A. Ormseth *et al.* 2020). What follows are any recent significant changes to the fishery or management measures.

Description of the Directed Fishery

There is no federally-managed directed fishery for octopus in the BSAI. The State of Alaska allows directed fishing for octopus in state waters under a special commissioner's permit. Since 2006, few permits have been requested and catch of octopus in state waters has been incidental to other fisheries (Bowers *et al.* 2010; Sagalkin and Spalinger 2011).

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 NMFS Alaska Regional Office catch accounting system. Total incidental catch range from approximately 200-400 t with high year-to-year variability. In 2011, the catch for octopus in BSAI exceeded the OFL 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 was introduced. Since then, all catches have been nearly an order of magnitude below the recommended ABC. See **Table 22.** for a time series of the total catch, TAC, ABC and OFL the octopus fishery.

Data

Fishery

See **Table 22.** 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

Biomass Estimates from Trawl Surveys

Biomass estimates for the octopus species complex based on bottom trawl surveys are shown in **Table 22.2?**. EBS shelf surveys are annual, except for 2020, when the survey was canceled due to the COVID-19 pandemic. The AI surveys are in even years and the 2020 survey in this area was also canceled. EBS slope surveys were conducted irregularly and the last survey was in **2016?**. Biomass estimates in the EBS and AI show high year-to-year variability, ranging over two orders of magnitude. There is a large sampling variance associated with estimates from the shelf survey because of a large number of tows that have no octopus. It is impossible to determine how much of the year-to-year variability in estimated biomass reflects true variation in abundance and how much is due to sampling variation. In 1997, the biomass estimate from the shelf survey was only 211 t, approximately equal to the estimated BS commercial catch. This suggests that the 1997 biomass estimate was unreasonably low. On the EBS shelf,

biomass estimates between 2013 and 2016 increased from 1,772 t to 7,441 t (**Table 22.2**)?. Overall biomass estimates have been on a declining trend since 2016, with an estimate of 4,914 t on the EBS shelf in 2022; this is a 34% decline over that period and a 3% decline from 2021 to 2022. Like the EBS, the AI biomass estimate peaked in 2016 and there were declines since then; there was a 41% decrease in 2018 and a 34% decrease in 2022 (or a 61% decreased over that time period.) Although biomass was not typically greater in one area, since 2018 biomass estimates on the EBS shelf (average 4,950 t) have been higher than the AI (1,868 t) (**Table 22.2**)?.

Other Data

The model used for the octopus assessment relies on diet data from Pacific cod, octopus's main predator in the BSAI. Fortunately because Pacific cod is an important commercial species, the AFSC food habits group collects a large number of Pacific cod stomachs for diet analysis (see **Table ???**).

Analytical approach

General Model Structure

The available data do not support quantitative catch-at-age modeling for either individual species of octopus in the BSAI or for the multi-species complex, and reliable biomass estimates are unavailable 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) (Connors *et al.* 2011).

The 2011 BSAI octopus assessment introduced the methodology for examining population trends in octopus that is still used. This approach uses the underlying model from Tier 5, where MSY is obtained at $\frac{1}{2}$ the total natural mortality (in tons). For Tier 5 stocks, the total natural mortality is usually estimated as the product of biomass (B) and an instantaneous mortality rate (M), $N=MB$. 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. This method uses 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. Because Pacific cod is an important commercial species, the AFSC food habits group collects a large number of Pacific cod stomachs for diet analysis (see **Table ???**). The amount of octopus consumed by Pacific cod is 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. This analysis was originally performed in 2011 using stomach data through 2008 (Connors *et al.* 2011). Prior to this years consumption estimator update, the consumption estimator was last updated for the 2016 assessment (Connors *et al.* 2016).

Parameter Estimates

Total Natural Mortality (N)

N was estimated using previously defined methods. See "General Model Structure" for a description.

Results

Harvest Recommendations

Amendment 56 Reference Points/ Specification of OFL and Maximum Permissible ABC

Since 2011, the Plan Team and SSC have used an alternative method based on biological reference points

derived from consumption estimates for 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) to set $OFL = N$ and $ABC = 0.75 * OFL$. **When this method is used, 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.

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.
- Bowers, F.R., Schwenzfeier, M., Herring, K., et al. (2010) Annual management report of the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea, and the westward region's shellfish observer program, 2008/09. ADF&G Fishery Management Report No 10-24.
- Boyle, P. and Rodhouse, P. (2005) *Cephalopods: Ecology and Fisheries*. Blackwell Publishing, Oxford, UK.
- Connors, 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.
- Connors, 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.
- 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.
- Olav A. Ormseth, Elizabeth M. Connors, 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.
- Sagalkin, N.H. and Spalinger, K. (2011) Annual management report of the commercial and subsistence shellfish fisheries in the Kodiak, Chignik, and Alaska peninsula areas, 2010. ADF&G Fishery Management Report No. 11-43.
- Wülker, G. (1910) Über Japanische cephalopoden: Beiträge zur kenntnis der systematik und anatomie der dibranchiaten. *Abhandlungen der Mathematisch-Physikalischen Classe der Königlich Bayerischen Akademie der Wissenschaften* 1, 1–77.

Tables

Table 22-1. 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 September 29, 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.

Year	Target Fishery					OFL	ABC	TAC	Catch/ABC
	P.cod	Flatfish	Other	Total	Retained				
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 September 29, 2023 from the NMFS Alaska Regional Office using the AKFIN database (<http://www.akfin.org>).

Table 22-2. 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
1984	581
1985	793
1986	1,351
1987	790
1988	573
1989	1,678
1990	1,157
1991	1,597
1992	1,903
1993	2,317
1994	2,397
1995	2,420
1996	1,336
1997	1,165
1998	1,272
1999	1,313
2000	1,405
2001	1,428
2002	1,333
2003	1,796
2004	0
2005	449
2006	705
2007	583
2008	1,208
2009	1,345
2010	1,198
2011	1,550
2012	1,838
2013	1,657
2014	1,644
2015	1,942
2016	1,954
2017	1,611
2018	1,619
2019	1,246
2020	0
2021	1,565
2022	985
2023	1,139

Table 22-3. Survey biomass estimates (t) for octopus species from the Aleutian Islands.

	<i>B. leioderma</i>		<i>J. diaphana</i>		<i>E. dofleini</i>		<i>Benthoctopus sp</i>		<i>S. salebrosus</i>		<i>B. oregonensis</i>		octopus unid.		Total	
Year	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
1991	57	50			57	45							1,046	22	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	7	50			623	25							762	48	1,393	28
2004			0	100	4,076	35	0	100					19	99	4,095	34
2006	1	100			3,037	17							24	71	3,062	17
2010					3,074	30							1	55	3,075	30
2012	31	63			2,739	42			1	80			8	100	2,779	42
2014	5	71			2,762	20			0	100			78	22	2,845	20
2016	0	94			3,752	24	4	100	1	100	1	100	75	100	3,833	24
2018	1	71	4	100	2,231	40			0	100			38	100	2,274	39
2022	0	100			1,505	23							0	100	1,505	23

Table 22-4. Survey biomass estimates (t) for octopus species from the EBS shelf.

[illegible]

Table 22-5. Survey biomass estimates (t) for octopus species from the EBS slope.

	<i>B. leioderma</i>		<i>J. diaphana</i>		<i>O. californiana</i>		<i>G. boreopacifica</i>		<i>E. dofleini</i>	
Year	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
2002	149	28					141	14	410	39
2004	291	14	4	44			245	39	993	24
2008	151	20	10	31			81	41	336	33
2010	87	21	1	100	15	100	96	46	216	33
2012	146	32	5	61			248	27	647	43
2016	133	20	9	50			143	16	566	31
	<i>Benthoctopus sp</i>		<i>S. salebrosus</i>		<i>B. oregonensis</i>		octopus unid.		Total	
Year	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
2002	236	20					34	49	971	18
2004	119	38	72	14			256	38	1,980	14
2008	0	100	23	16	27	40	152	32	781	17
2010	77	22	32	17	28	99	70	24	621	15
2012			28	16			343	22	1,419	21
2016			51	18	151	27	1,211	19	2,263	13

Figures

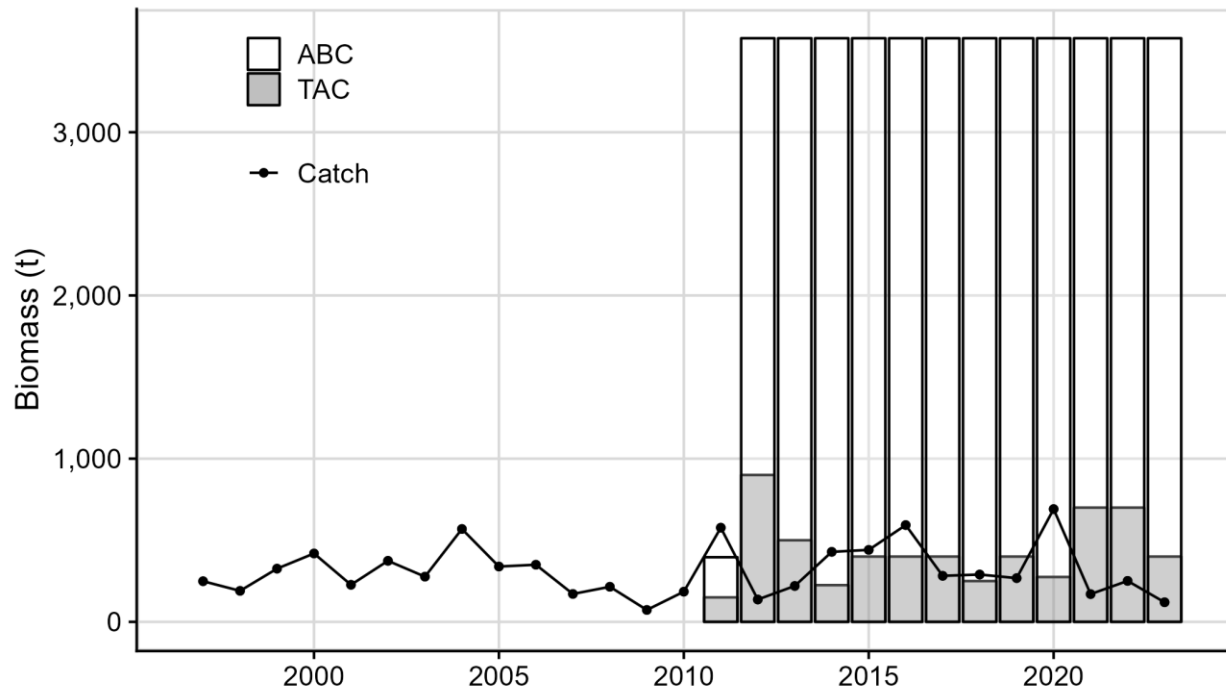


Figure 22-1. Octopus catch (retained and discarded), ABC and TAC from 1997-2023. Data reflect catch posted through September 16, 2023 (sourced September 29, 2023 from the NMFS Alaska Regional Office using the AKFIN database (<http://www.akfin.org>)).

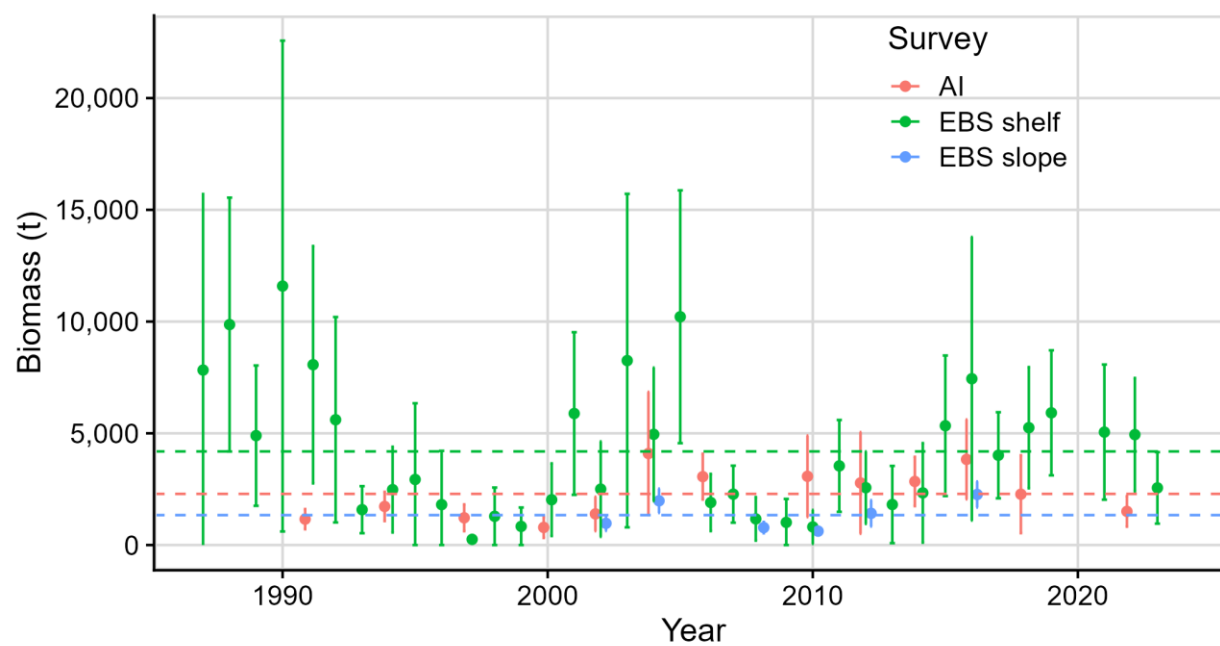


Figure 22-2. Octopus biomass estimates from the EBS shelf (1987-2023), EBS slope (2002-2016) and AI (1991-2002) surveys. The horizontal dashed lines represent the long-term average biomass for the survey with the same color.