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 BSAI "other species" complex, along with sharks, skates, and sculpins. Historically, catches of the other species complex were well below TAC and retention of other species was small. Due to increasing market values, retention of some of the other species complex members increased. Beginning in 2011, the BSAI Fisheries Management Plan was amended to provide separate management for sharks, skates, sculpins, and octopus, and set separate catch limits for each species group. Catch limits for octopus for 2011 were set using Tier 6 methods based on the maximum historical incidental catch rate. In 2012, a new, alternative Tier 6 methodology was developed. This approach uses the underlying model from Tier 5, where the natural mortality rate is a predation-based estimate of octopus by Pacific cod, as a conservative measure. This method has been in use since 2012 (Connors et al, 2011), consumption data was updated in 2016 (Connors et al, 2016), and this model is recommended for 2023 and 2024.

In this 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 most abundant in eastern Bering Sea (EBS) shelf waters and predominates in the commercial catch. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the BSAI; a portion of the catch is retained or sold for human consumption or bait.

The Bering Sea and Aleutian Island trawl surveys produce estimates of biomass for octopus, but these estimates are highly variable and do not reflect the same sizes of octopus caught by industry. Examination of size frequency from survey and fishery data shows that both commercial and survey trawls catch predominantly small animals (<5 kg), while commercial pot gear catches or retains only large animals (10-20 kg). In general, the state of knowledge about octopus in the BSAI is increasing, but there is still no reliable estimate of octopus biomass, and we recommend continued management in Tier 6.

Summary of Changes in Assessment Inputs

1) Incidental catch data have been updated through October 12, 2022.

2) Biomass estimates from the 2021 and 2022 EBS shelf trawl surveys, and the 2022 Aleutian Islands trawl survey are presented. The EBS shelf and Aleutian Islands surveys were not conducted during 2020 due to the COVID-19 pandemic. The last BS slope survey was conducted in 2016.

Summary of Results

1) After several years of relatively low catches, the 2020 catch is the largest in the time series (691 t). As of October 12, 2022, catch in 2021 and 2022 were substantially lower (170 and 235 t, respectively.)

2) New biomass estimates are available from 2021 and 2022 EBS shelf trawl surveys and the 2022 Aleutian Islands trawl survey. There was a 34% decline in estimated biomass in the Aleutian Islands and a 3% decline on the EBS shelf.

3) We continue to use the approved alternative methodology for setting octopus catch limits in the BSAI under Tier 6. This method uses a predation-based estimate of total natural mortality and the logistic fisheries model to set the OFL based on a highly conservative estimate of total natural mortality.

Harvest Recommendations

Quantity	As estimated or *specified last year* for: 2022	2023	As estimated or *recommended this* year for: 2023	2024
Tier 6 (consumption estimate)				
OFL (t)	4,769	4,769	4,769	4,769
ABC (t)	3,576	3,576	3,576	3,576
Status	As determined *in last year* 2019	2020	As determined *this* year for: 2021	2022
Overfishing	n/a	n/a	n/a	n/a

Introduction

Description and General Distribution

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 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.

Data

Incidental Catch Data

Prior to 2003, there was little market for octopus and no directed fishery in federal waters; historical rates of incidental catch (prior to 2003) do not necessarily reflect fishing patterns where octopus are part of retained market catch. Estimates of incidental catch (Table 22.1) suggest substantial year-to- year variation in harvest, some of which is due to changing regulations and market forces in the Pacific cod fishery. A large interannual variability in octopus abundance is also consistent with anecdotal reports (Paust 1988, 1997) and with life-history patterns for *E. dofleini.*

Reported harvest of octopus from incidental catch in state fisheries in the BSAI ranged from 18-69 t between 1996 and 2002 but was 100-300 t in 2003-2006 (Sagalkin and Spalinger 2011). From 1992-2002 total incidental catch of octopus in federal waters, estimated from observed hauls, was generally between 100 and 400 t in the Pacific cod and flatfish target fisheries (where flatfish does not include Pacific halibut) (Table 22.1). Since 2003, the total octopus catch in both state and federal waters (including discards) has been estimated using the NMFS Alaska Regional Office catch accounting system. Total incidental catch during this period has continued to be 200-400 t in most years, with an average of 325 t, but there was very high year-to year variation over much of this period. Total catch was generally high (300-500 tons) from 2003-2006 and low (<200 tons) from 2007-2010, with only 73 tons caught in 2009. The low octopus catch during this period may be a result of a decline in processor demand and a drop in cod pot-fishing effort due to a decline in the market price of cod and increased fuel prices. Catch in 2011 was the highest observed to that date, reaching 534 tons by mid-October. On September 1, 2011, the NMFS Regional Office prohibited retention of octopus because the TAC of 150 tons had been reached. Catch rates for Pacific cod and incidental catch rates for octopus were both very high during fall 2011 and the octopus OFL of 528 t was reached; the NMFS closed directed fishing for Pacific cod with pot gear in the BSAI on October 21, 2011. As in previous years, the majority of the 2011 catch came from Pacific cod fisheries, primarily pot fisheries in statistical reporting areas 519, 517, and 509 (Table 22.1).

Since an alternative Tier 6 method was introduced in 2012, all catches were still nearly an order of magnitude below the recommended ABC. The highest catch in the time series was in 2020, at 691 t. The percentage of BSAI octopus retained is variable and has increased since 2016 (as much as 34%, in 2017). Since octopus were separated from the Other Species group and managed as the Octopus complex in 2011, catches have been substantially below ABCs, ranging from 5% to 22% of the ABC each year since 2021 (Table 22.1). In 2021, catch was only 5% of ABC and in 2022, it is 7%, as of 10/12/2022.

AFSC Survey Data

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).

Analytic 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 ½ 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. 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 (Conners et al. 2011). The consumption estimator was updated for the 2016 assessment (Conners 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 Petreyra 1969, Francis 1974) to set OFL = N and ABC = 0.75*OFL. **When this method is used, the resulting catch limits are OFL = 4,769 t and ABC = 3,576 t which are our recommended 2023 and 2024 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.

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Tables

Table 22.1. Estimated catch (t) of all octopus species in the Bering Sea and Aleutian Islands, by target fishery. Catches from 1997-2002 are sourced from the Alaska Regional Office (AKRO) blend data; 2003-2022 data are from AKRO catch accounting. Catch is shown separately for the two target fisheries that have the highest rate of incidental octopus catch, Pacific cod and flatfish (all species), and all other target fisheries combined. Pacific halibut are included in the "other" category. Octopus were managed in the "Other species" group until 2011. An alternative Tier 6 method was adopted in 2012.

	Target Fishery							
Year	P. cod	Flatfish	Other	Total	OFL	ABC	Catch/ABC	Other Spp.
1997	160	86	3	248				x
1998	168	13	9	190				x
1999	310	14	2	326				x
2000	359	57	3	418				x
2001	211	9	7	227				x
2002	334	21	19	374				x
2003	224	32	21	277				x
2004	278	44	246	569				x
2005	311	17	10	339				x
2006	331	5	9	350				x
2007	156	7	8	171				x
2008	196	11	6	215				x
2009	58	10	5	73				x
2010	168	12	5	185				x
2011	555	9	14	577	528	396	109%	
2012	126	4	8	137	3,450	2,590	5%	
2013	214	2	4	220	3,450	2,590	8%	
2014	406	5	18	429	3,450	2,590	17%	
2015	412	6	24	441	3,452	2,589	17%	
2016	554	5	34	593	4,769	3,576	17%	
2017	264	4	14	282	4,769	3,576	8%	
2018	262	5	23	290	4,769	3,576	8%	
2019	238	13	17	268	4,769	3,576	7%	
2020	672	3	16	691	4,769	3,576	19%	
2021	154	8	8	170	4,769	3,576	5%	
*2022**	*207*	*8*	*20*	*235*	4,769	3,576	7%	

*2022 data are incomplete; retrieved October 12, 2022.

Table 22.2 Survey biomass estimates (t) for octopus species and in total in the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions. CV = coefficient of variation. "Octopus unID" is octopus unidentified. Species include *Benthoctopus leioderma, Benthoctopus oregonensis, Enteroctopus dofleini,* octopus unidentified (octopus unID)*, Sasakiopus salebrosus, Japetella diaphana, Opisthoteuthis californiana, Graneledone boreopacifica*, and *Benthoctopus* spp. There were no surveys in 2020.

		B leioderma		*B oregonensis*		*E dofleini*		octopus unID		*S salebrosus*	
		Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
	2010	27	83%	0		642	59%	0		142	58%
	2011	249	39%	0		2,833	33%	0		0	
	2012	478	37%	0		2,088	39%	0		0	
	2013	97	50%	13	100%	1,657	53%	4	85%	0	
EBS	2014	157	60%	93	100%	2,078	54%	0		4	100%
Shelf	2015	113	63%	0		5,223	31%	0		0	
	2016	327	35%	0		6,927	47%	0		188	46%
	2017	1,578	27%	0		1,777	44%	0		0	
	2018	603	37%	0		4,648	29%	0		0	
	2019	353	41%	0		5,538	26%	7	100%	0	
	2021	27	70%	0	100%	5,026	31%	1	68%	0	
	2022	243	91%	43	64%	4,628	28%	0	101%	0	
	2010	260	12%	83	57%	649	19%	0	58%	96	10%
EBS	2012	439	19%			1,942	25%	4	46%	85	9%
Slope	2016	398	12%	453	16%	1,697	18%	16	51%	153	10%
	2010					3,074	30%	1	53%		
	2012					2,739	42%	41	52%		
	2014					2,762	20%	83	60%		
AI	2016					3,752	24%	81	94%		
	2018					2,231	40%	44	87%		
	2022					1,505	23%	0	83%		

Table 22.2 continued.

		J diaphana		*O californiana*		*G boreopacifica*		*Benthoctopus sp*		Total	
		Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
EBS Shelf	2010									811	48%
	2011									3,083	31%
	2012									2,566	32%
	2013									1,772	50%
	2014									2,332	49%
	2015									5,336	30%
	2016									7,441	44%
	2017									3,355	26%
	2018									5,251	26%
	2019									5,898	24%
	2021									5,054	31%
	2022									4,914	26%
EBS Slope	2010	2	58%	211	14%			231	13%	1,532	9%
	2012	15	35%	1,026	13%	744	16%			4,255	12%
	2016	26	29%	3,618	11%	428	9%			6,789	8%
AI	2010									3,075	30%
	2012									2,779	42%
	2014									2,845	20%
	2016									3,833	24%
	2018									2,274	39%
	2022									1,505	23%