Evaluation of the potential for stock structure in the Bering Sea/Aleutian Islands octopus complex

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Introduction

The stock structure template is designed to evaluate the spatial structure of populations of individual species and determine whether managing those populations at a spatial scale larger than the scale of subpopulations poses a conservation risk. Applying this template to the Bering Sea and Aleutian Islands (BSAI) octopus complex is problematic because (1) it is a complex of individual species, so "stock structure" of the complex does not exist; (2) evaluating stock structure for individual species, including the predominant species, *Enteroctopus dofleini,* is hampered by limited data availability; and (3) there are no directed fisheries for octopus. This document addresses the goals of the stock structure evaluation by analyzing spatial differences in species composition and relevant spatial patterns in commercial fishery removals, and evaluating the potential for stock structure in *E. dofleini*.

Overview of the BSAI octopus complex

Detailed information for the BSAI octopus complex is available in the annual Stock Assessment and Fishery Evaluation reports (Ormseth et al. 2018) and is not repeated here. Scientific knowledge of octopuses in the BSAI, including which species actually inhabit the region, is very limited. There are at least eight species of octopuses representing seven genera found in the Bering Sea (Table 1). They occur in depths from less than 10 m to greater than 1500 m. All but one, *Japetella diaphana*, are benthic. The mesopelagic *Vampyroteuthis infernalis* is a cephalopod that shares similarities with both octopuses and squids, but is included in the octopus complex.

The available data suggest that the species composition of the octopus complex varies substantially by area. The highest octopus species diversity occurs on the eastern Bering Sea (EBS) slope between 200 and 750 m (Table 2 and Figure 1). On the EBS shelf and in the Aleutian Islands (AI) the complex is less diverse and dominated by *E. dofleini*. Recent (2017 & 2019) observations in the northern Bering Sea (NBS) indicate a different species composition there, mainly due to the rarity of *E. dofleini* (Figure 1). Although survey biomass estimates are highly uncertain (see below), octopus biomass appears to be highest on the outer region of the EBS shelf and in the AI (Table 2; Figures 2 and 3). There are no directed fisheries for octopus but they are caught incidentally in various fisheries. Most of the incidental catch occurs in pot fisheries for Pacific cod; octopus in catches are not identified to species but the size distribution indicates most octopus are likely *E. dofleini* (Ormseth et al. 2018).

Application of stock structure template

<u>Harvest and trends</u>

Limitations of the data: Limited information is available for analyzing the abundance and distribution of octopus and the population structure of individual octopus species. This is mainly due to the inadequacy of the AFSC bottom trawl surveys for sampling octopus species. Octopus often inhabit rocky areas of the seafloor that are typically excluded from trawl surveys. In addition, octopus spend a large amount of time in dens, reducing their availability to trawls. As a result, survey catches of octopus are spotty and are not indicative of octopus presence in the trawled area. While the surveys probably underestimate octopus biomass, biomass estimates have high coefficients of variation (CVs; Table 2) and have limited utility for monitoring trends in abundance.

Exploitation rates: Exploitation rates of octopus were estimated for the four years where all three standard BSAI surveys were conducted (Table 3). Due to the data limitations described above, this analysis likely overestimates the degree of octopus exploitation. Exploitation rates were higher in the EBS (0.032-0.092) than in the AI (0.003-0.016). The natural mortality rates of the octopus species in the complex are not known, but octopus are generally short lived (2-5 years; Ormseth et al. 2018) and these exploitation rates can be considered relatively low.

Spatial distribution of catch relative to biomass: The spatial distribution of commercial octopus catch is dependent primarily on the location of the pot gear fishery for Pacific cod and is concentrated in the area immediately north of Unimak Pass and the Alaska Peninsula (Figures 4 and 5). Because octopus are distributed widely along the outer EBS shelf and throughout the AI, this pattern of catch represents a mismatch between the distribution of catch and biomass (Table 4).

Population trends: As discussed above, octopus biomass estimates are highly uncertain and the trawl survey time series is probably not very useful for examining trends. However, the estimated biomass of all octopus species combined (Figure 6) suggests the possibility of decadal patterns in abundance. Biomass estimates of *E. dofleini* since 2010 (the first year when species-specific identification is considered reliable) suggest high abundance in 2016, although the uncertainty is high (Figure 7).

Note: Because E. dofleini is the predominant species in the BSAI and is the only species to have received significant research attention, the following sections on behavior and genetics are limited to that species.

<u>Behavior and movement</u>

The extent of movement by adult (immature and mature) *E. dofleini* in Alaska and other regions appears to be relatively limited. The mean home range of this species in British Columbia was estimated at 250 m^2 (Mather et al. 1985), and adults in the same area showed average linear movements of 13.2 m away from den sites (Hartwick et al. 1984). Adults also engaged in highly sedentary behavior, spending much of their time hidden in dens. In Prince William Sound, Alaska, adults monitored with acoustic tags were stationary 94% of the time and the maximum horizontal movement was 4.8 km (Scheel and Bisson 2012). In the southern EBS near Unimak Pass, the extent of horizontal movement by marked octopus was positively influenced by individual size and the amount of time between mark and recapture (Brewer et al. 2015). Adults at liberty for more than one season showed an average horizontal movement of 2.14 km, with a maximum movement of 11.5 km.

Limited movement of adults likely reduces the amount of mixing among *E. dofleini* over large distances, a phenomenon that could lead to a highly structured population. In contrast, larval *E. dofleini* are pelagic and may have greater potential for dispersal (Ormseth et al. 2018). Very little information exists regarding this life stage, but the EBS and AI are highly advective environments that could facilitate larval dispersal.

<u>Genetics and identification of new species</u>

The few studies that have explored genetic differentiation in *E. dofleini* contain conflicting evidence regarding population structure and raise the possibility of multiple species. Microsatellite analysis of *E. dofleini* in the Pacific Northwest suggested moderate population structuring (Larson et al. 2015). The F_{ST} values (a measure of genetic variance) among 4 regions varied from 0.101 to 0.237, although other analysis suggested significant overlap among geographically separated groups.

In contrast, genetic analyses of *E. dofleini* in Alaska found little evidence of population structure. Toussaint et al. (2012) used a variety of techniques to compare individuals from the southern EBS (SEBS), the central Gulf of Alaska (CGOA), and Prince William Sound (PWS). They found evidence of two distinct lineages in PWS and suggested the existence of a cryptic new species (i.e. a separate species morphologically inseparable from the original species). Similarly, mitochondrial DNA was used to compare samples from the same locations as well as two sites in southeast Alaska (SEAK; Barry et al. 2013). This study found no evidence of isolation by distance or other clinal genetic differentiation, but did find two distinct haplotypes that coincided with distinct geographic regions (SEBS, CGOA, and Glacier Bay vs. PWS and inside waters of SEAK). These regions overlap spatially, which suggests that genetic differentiation in *E. dofleini* is maintained through mechanisms other than geographic separation. Toussaint et el. (2012) suggest that vertical separation (i.e. inhabiting different depths) might isolate individuals reproductively.

It should be noted that these three studies were limited in their geographic scope and sample size, and much work remains to be done towards understanding genetic variation of *E. dofleini*. These early results suggest that population structuring may be relatively low in Alaska, perhaps as a result of larval dispersal. The structure observed in Pacific Northwest populations could be due to limited dispersal.

Management implications

While this report does address all of the various components of the stock structure template, the data have serious limitations and are insufficient to make conclusions regarding the patterns of exploitation of the octopus complex or population structuring in *E. dofleini*. The data that do exists yield the following observations:

1) Relative to our understanding of octopus distribution, octopus catches are disproportionately focused in the southeastern Bering Sea as a result of their prevalence in pot gear catches targeting Pacific cod. However, since exploitation rates are relatively low this is unlikely to pose a conservation concern.
2) There is good evidence that adult *E. dofleini* do not move over large distances, which might contribute to geographic isolation and a high degree of population structuring. However, the few studies of genetic differentiation in Alaska suggest this is not the case, and this may be due to dispersal of the planktonic larval life stage.
3) There is some evidence that *E. dofleini* may actually be two different species. More work needs to be done to confirm this. Considering that octopus have only recently been consistently identified to species in AFSC surveys, and are not identified to species in incidental fishery catches, the possible existence of an additional species is unlikely to complicate management and is a lower priority for research than other more basic information.

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Tables

Table 1. Taxonomy and life history of octopus species observed in the Bering Sea (BS) and Aleutian Islands (AI) regions.

			Common Name	General Distribution
Order	Vampyromorpha			
		Vampyroteuthis infernalis	vampire squid	Southeast BS slope below 300 m
Order	Octopoda			
Group	Cirrata			
Family	Opisthoteuthidae			
		Opisthoteuthis californiana	flapjack devilfish	BS deeper than 200 m
Group	Incirrata			
Family	Bolitaenidae			
		Japetella diaphana	pelagic octopus	Pelagic
Family	Octopodidae			
		Benthoctopus leioderma	smooth octopus	southern BS deeper than 250 m
		Benthoctopus oregonensis	none	BS shelf break
		Enteroctopus dofleini	giant octopus	all BSAI, from 50 - 1400 m
		Graneledone boreopacifica	none	BS slope 650 - 1550 m
		Sasakiopus salebrosus	stubby octopus	BS slope, 200 - 1200 m

Table 2. Biomass estimates in metric tons and coefficients of variation (CV) for octopus species in three areas of the Bering Sea and Aleutian Islands region. EBS = eastern Bering Sea; AI = Aleutian Islands. Biomass estimates for species other than *E. dofleini* in the AI are included in the "octopus unID" category.

		B. leioderma		*B. oregonensis*		*E. dofleini*		*octopus unID*		*S. salebrosus*	
		biomass	CV	biomass	CV	biomass	CV	biomass	CV	biomass	CV
EBS shelf	2010	27	0.84	0		650	0.59	0.0		142	0.58
	2011	250	0.39	0		2,844	0.33	459.6	1.00	0	
	2012	479	0.37	0		2,087	0.39	0.1	1.04	0	
	2013	97	0.50	13	1.00	1,654	0.53	4.4	0.79	0	
	2014	157	0.60	93	1.00	2,095	0.54	2.0	0.80	4	1.00
	2015	113	0.63	0		5,248	0.31	1.7	0.77	0	
	2016	328	0.35	0		6,997	0.47	0.8	1.01	188	0.46
	2017	1,583	0.27	0		1,793	0.44	10.4	0.50	0	
	2018	604	0.37	0		4,638	0.29	0.0		0	
EBS slope	2010	87	0.21	28	0.99	216	0.33	0.0	1.00	32	0.17
	2012	146	0.32			647	0.43	1.3	0.80	28	0.16
	2016	133	0.20	151		566	0.31	5.3	0.89	51	
AI	2010					3,074	0.30	1.1	0.53		
	2012					2,739	0.42	40.8	0.52		
	2014					2,762	0.20	83.1	0.60		
	2016					3,752	0.24	80.6	0.94		
	2018					2,231	0.40	43.6	0.87		

		J. diaphana		*O. californiana*		*G. boreopacifica*		*Benthoctopus sp.*		*V. infernalis*	
		biomass	CV	biomass	CV	biomass	CV	biomass	CV	biomass	CV
EBS shelf	2010										
	2011										
	2012										
	2013										
	2014										
	2015										
	2016										
	2017										
	2018										
EBS slope	2010	0.5	1.00	85	0.24	96	0.46	77	0.22	0.09	1.00
	2012	5.1	0.61	342	0.22	248	0.27				
	2016	8.6	0.50	1,206	0.19	143	0.16				
AI	2010										
	2012										
	2014										
	2016										
	2018										

Table 3. Estimated exploitation rates (catch/biomass) for the BSAI octopus complex in the 4 years where data are available from all three surveys. Survey biomass estimates are highly uncertain, so the exploitation rate estimates should be viewed with caution.

	Biomass (t)		Catch (t)		exploitation rate	
year	EBS	AI	EBS	AI	EBS	AI
2004	6,914	4,095	548	20	0.079	0.005
2010	1,441	3,075	133	49	0.092	0.016
2012	3,986	2,779	127	10	0.032	0.004
2016	9,776	3,833	585	11	0.060	0.003

Table 4. Proportions of octopus catch and estimated biomass occurring in the eastern Bering Sea (EBS) and Aleutian Islands (AI).

	Catch (t)		Biomass (t)	
	EBS	AI	EBS	AI
2003	0.92	0.08		
2004	0.96	0.04	0.63	0.37
2005	0.96	0.04		
2006	0.81	0.19		
2007	0.82	0.18		
2008	0.90	0.10		
2009	0.72	0.28		
2010	0.73	0.27	0.32	0.68
2011	0.98	0.02		
2012	0.93	0.07	0.59	0.41
2013	0.83	0.17		
2014	0.96	0.04		
2015	0.95	0.05		
2016	0.98	0.02	0.72	0.28
2017	0.88	0.12		
2018	0.44	0.56		

Figures

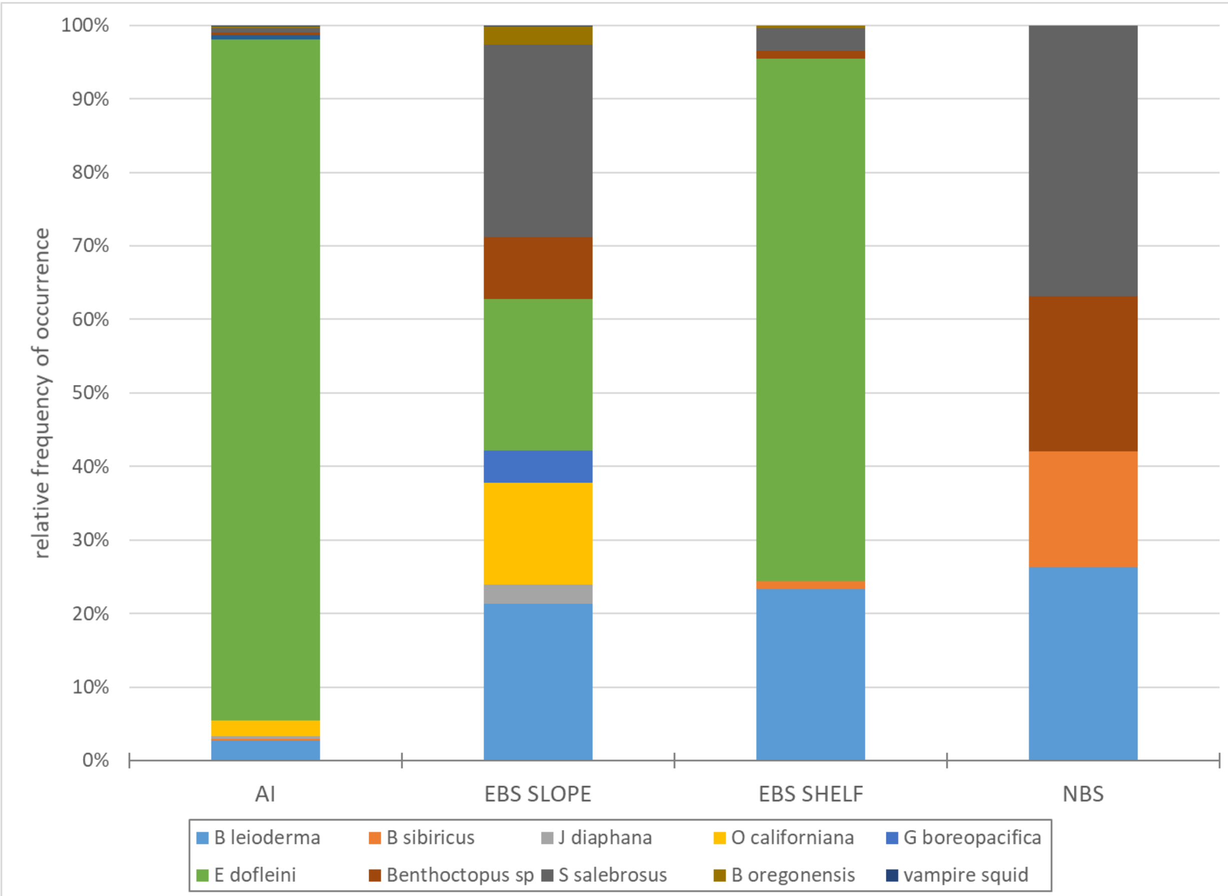

Figure 1. Species composition of octopus assemblages in four areas within the Bering Sea and Aleutian Islands region, based on relative frequency of occurrence. EBS = eastern Bering Sea; AI = Aleutian Islands; NBS= northern Bering Sea.

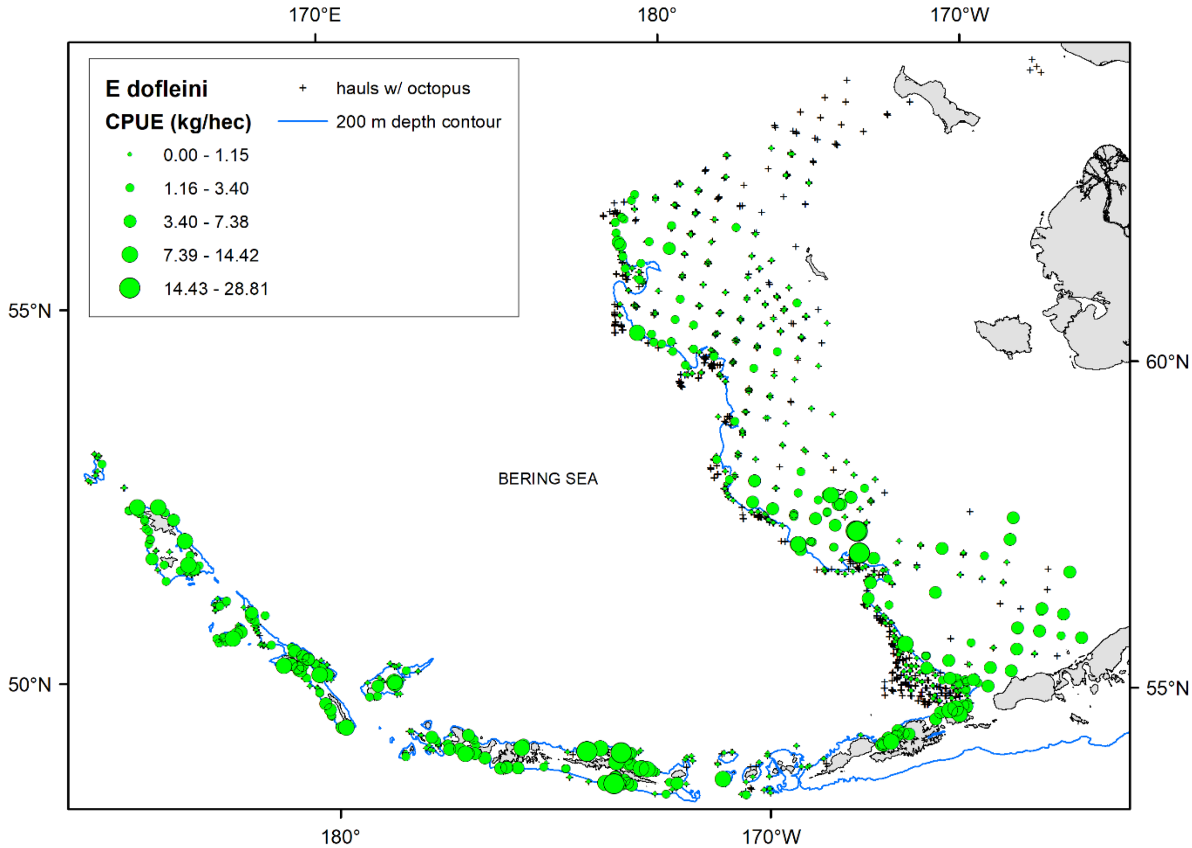

Figure 2. Distribution of *Enteroctopus dofleini* (giant Pacific octopus) in the Bering Sea and Aleutian Islands. Data are catch per unit effort (CPUE) from AFSC bottom trawl surveys at all survey stations sampled during 2000-2018. Crosses indicate hauls containing other octopus species.

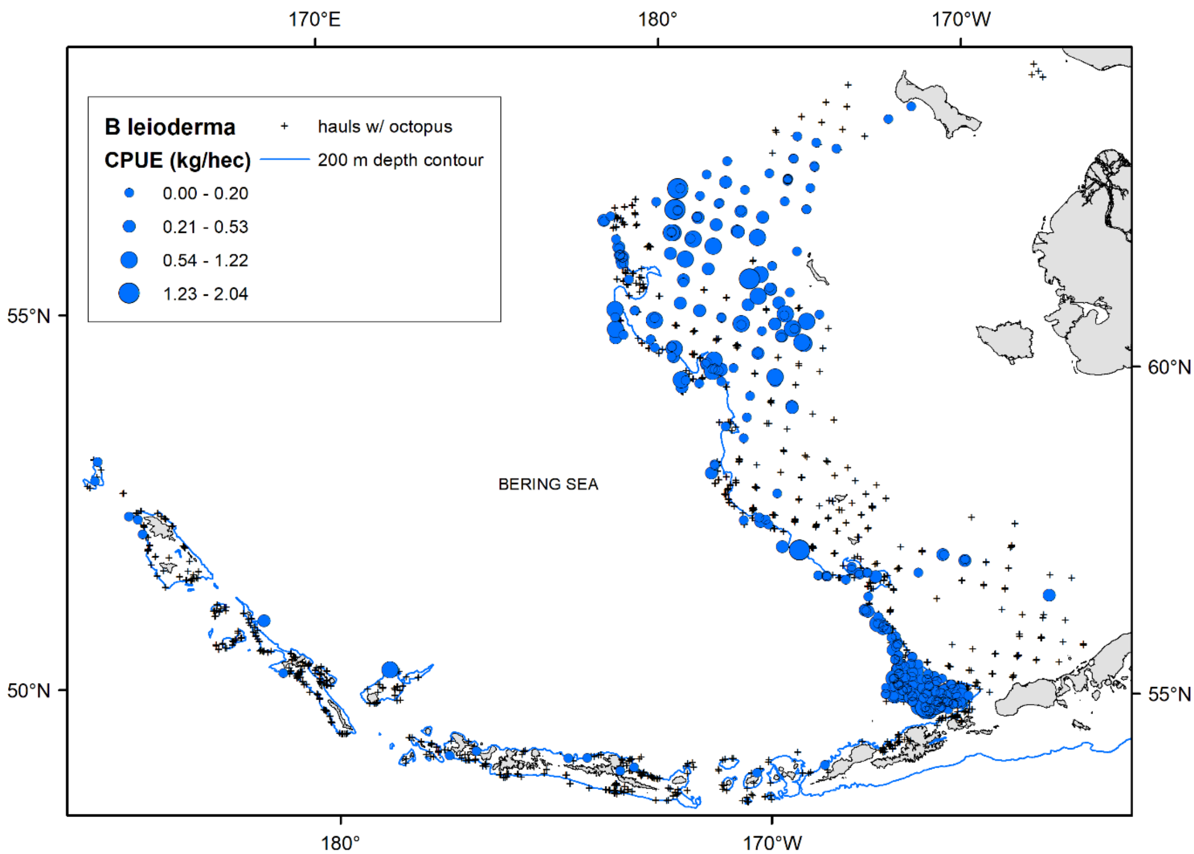

Figure 3. Distribution of *Benthoctopus leioderma* (smoothskin octopus) in the Bering Sea and Aleutian Islands. Data are catch per unit effort (CPUE) from AFSC bottom trawl surveys at all survey stations sampled during 2000-2018. Crosses indicate hauls containing other octopus species.

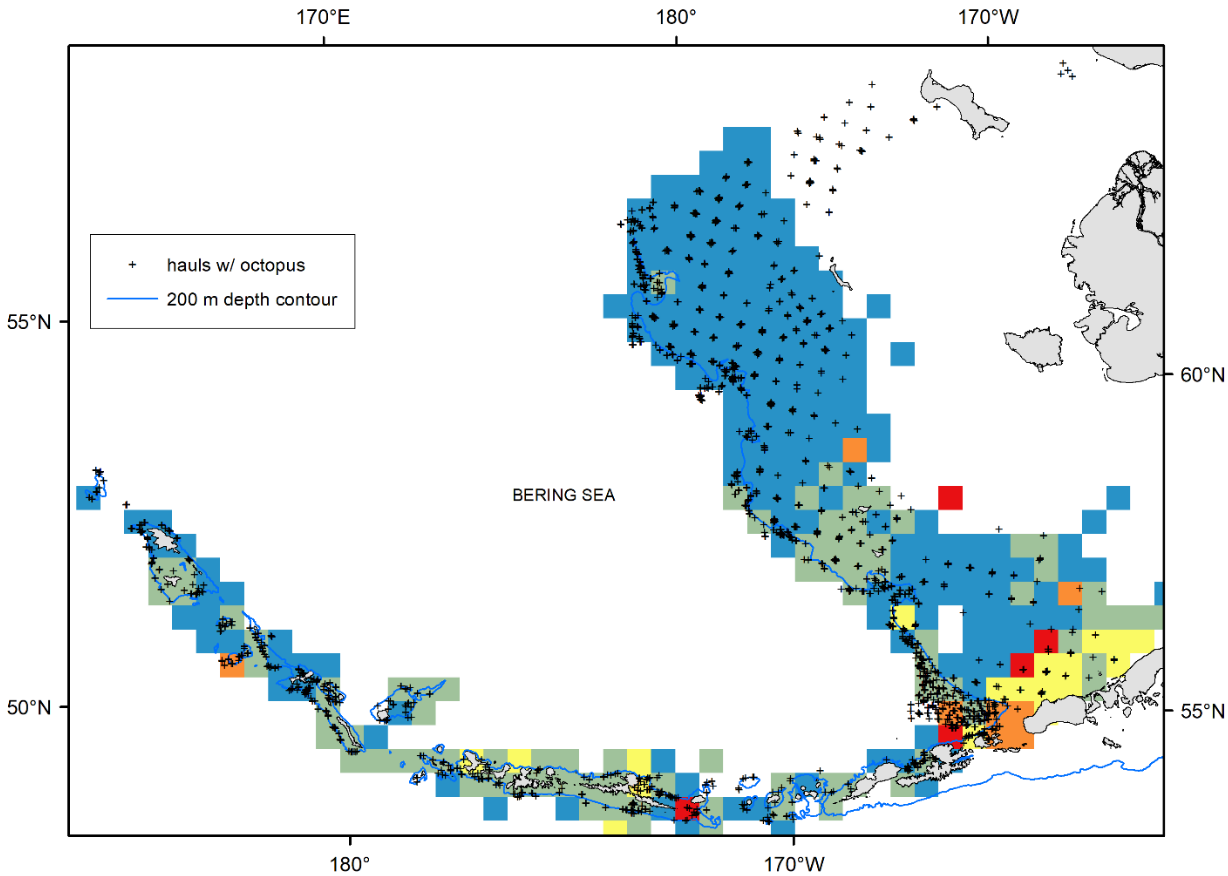

Figure 4. Mean observed catches of octopus (all species) in commercial fisheries during 2009-2018. Data are based on estimated octopus catches in all observed hauls; means are based on all observed hauls within each 40 km X 40 km grid cell.

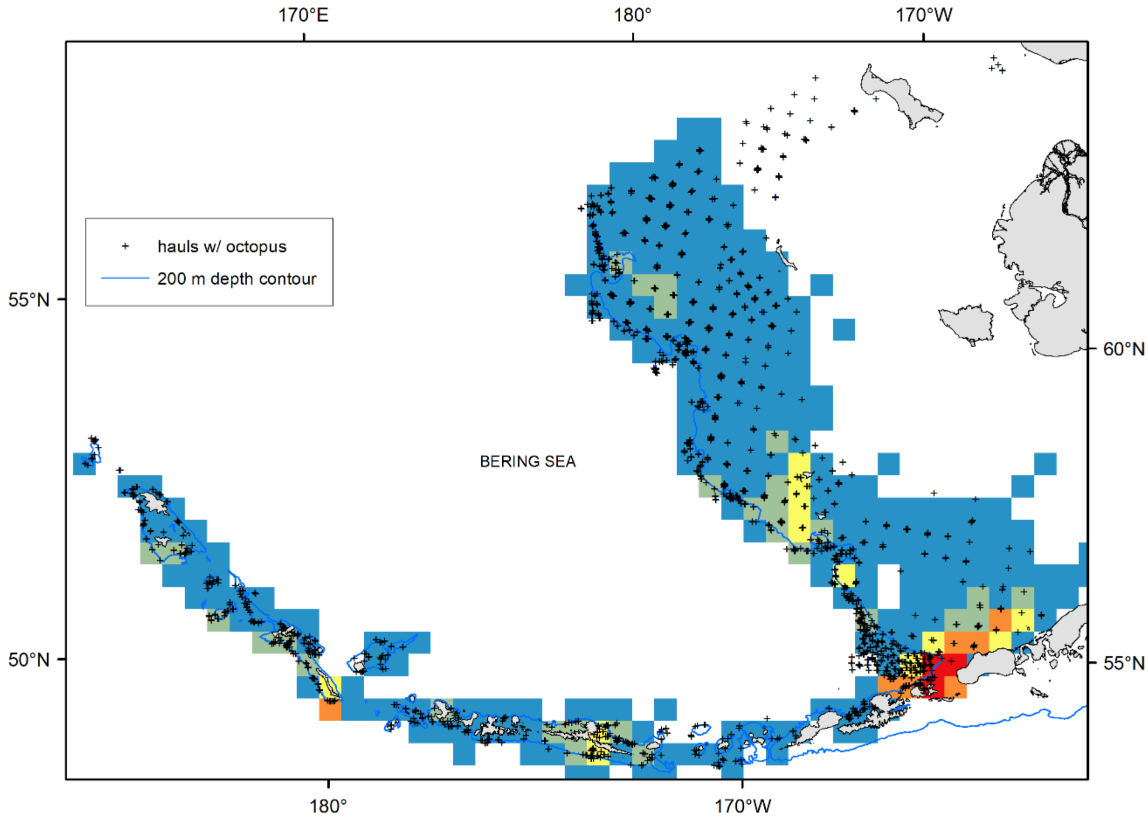

Figure 5. Total observed catches of octopus (all species) in commercial fisheries during 2009-2018. Data are based on estimated octopus catches in all observed hauls, summed within each 40 km X 40 km grid cell.

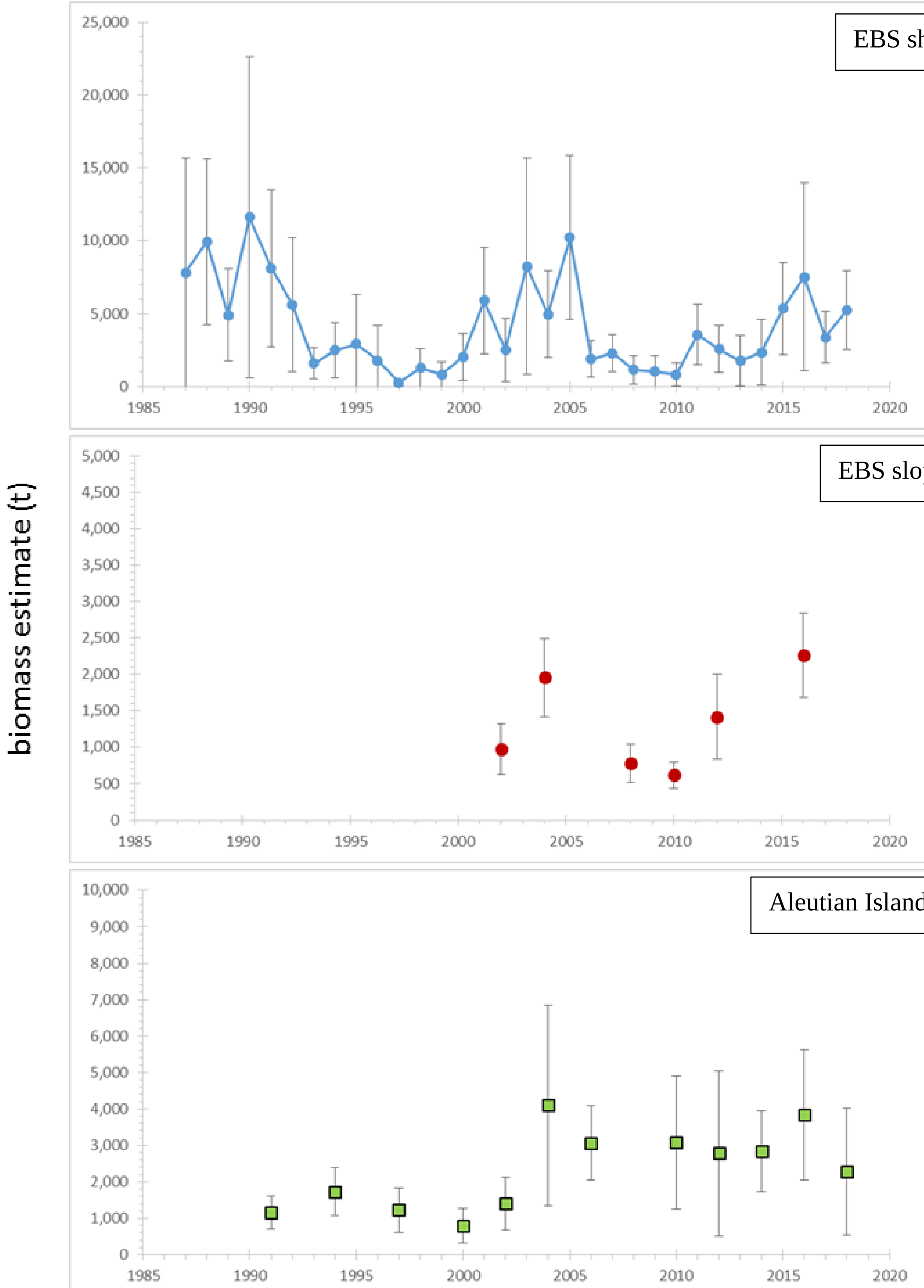

Figure 6. Biomass estimates (t) of octopus (all species) from AFSC bottom trawl surveys in three areas: EBS shelf (top), EBS slope (middle), and AI (bottom), 1987-2018. Error bars indicate 95% confidence intervals. Note that scale of y-axis varies among plots.

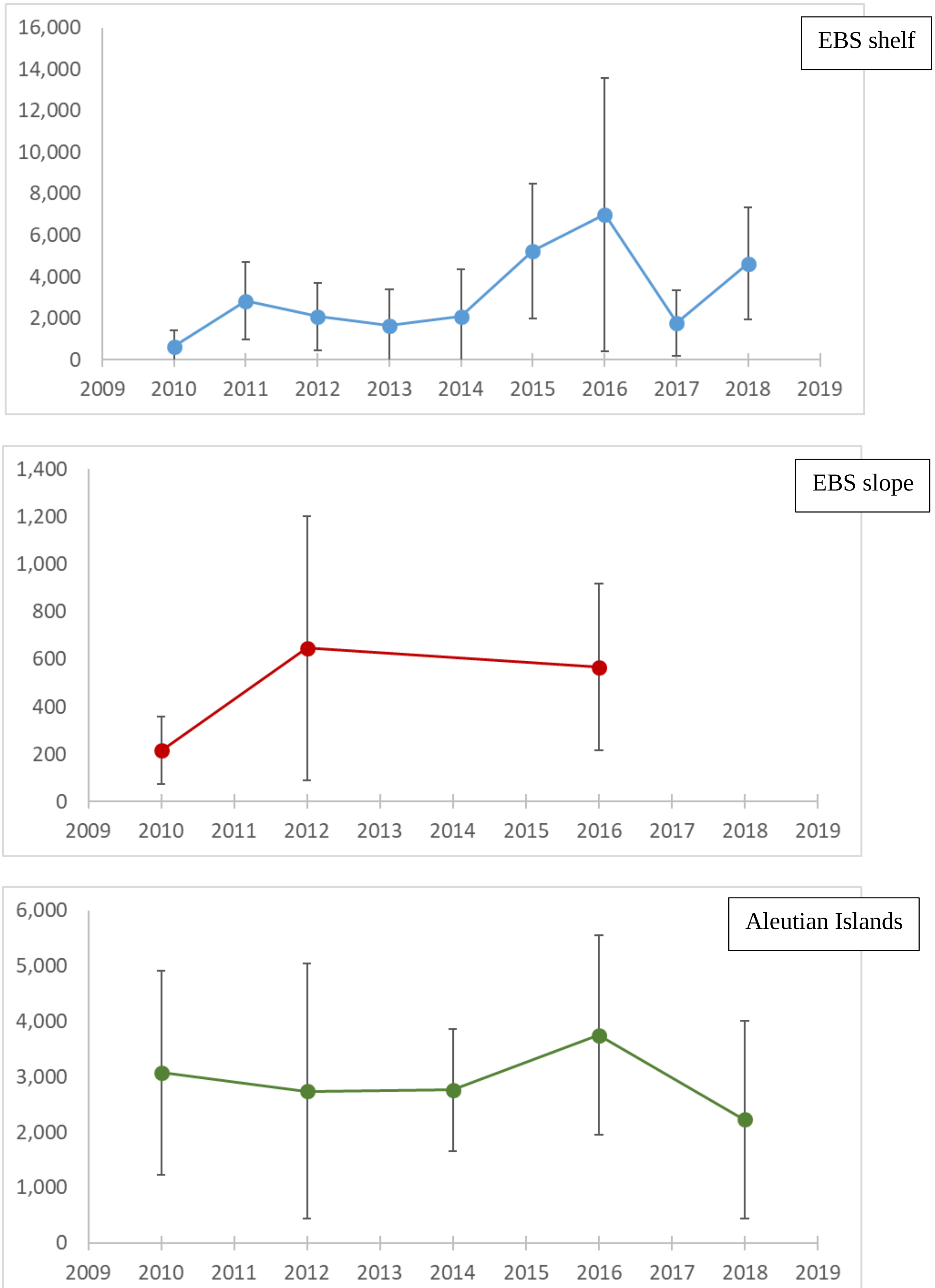

Figure 7. Biomass estimates (t) of *Enteroctopus dofleini* from AFSC bottom trawl surveys in three areas: EBS shelf (top), EBS slope (middle), and AI (bottom), 2010-2018. Error bars indicate 95% confidence intervals. Note that scale of y-axis varies among plots.