Patterns in octopus predation by Pacific cod, *Gadus macrocephalus*, in the Eastern Bering Sea

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Introduction

Pacific cod are generalist predators with evident trophic ontogeny, and have a widespread distribution across subarctic shelf regions of the North Pacific Ocean. Pacific cod stomachs have been collected since 1981 during annual bottom trawl surveys of the Eastern Bering Sea continental shelf (EBS shelf) conducted by the Resource Assessment and Conservation Engineering division at the Alaska Fisheries Science Center. Consumption estimates of octopus by Pacific cod are used as a basis for estimating mortality and minimum biomass of the octopus complex in the Eastern Bering Sea/Aleutian Islands management area (Conners et al., 2014). Since 2011, these diet-based estimates have been used to set the fishing quota for octopus in the Eastern Bering Sea/Aleutian Islands. While there is no directed fishery for octopus in Alaska, they are frequently taken as incidental catch.

The purposes of this study were to:

- Explore spatial and ontogenetic patterns in octopus predation by Pacific cod across the EBS shelf.
- Examine octopus size-selectivity biases between Pacific cod and conventional bottom-trawl surveys conducted by the Alaska Fisheries Science Center.

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Methods

- Stomach contents of 38,614 Pacific cod from the standard survey area were identified, counted and weighed by analysts in the Resource Ecology and Ecosystem Modeling Program's Trophic Interactions Laboratory at the Alaska Fisheries Science Center.
- Length measurements of keratinous mandibles ("beaks", **Fig 1**) were used to estimate initial prey body mass (reconstructed mass) for octopus identified in 2006 and 2009-2011 stomach samples.

Figure 1. Pigmented hood length measurements for lower (left) and upper (right) keratinous mandibles.

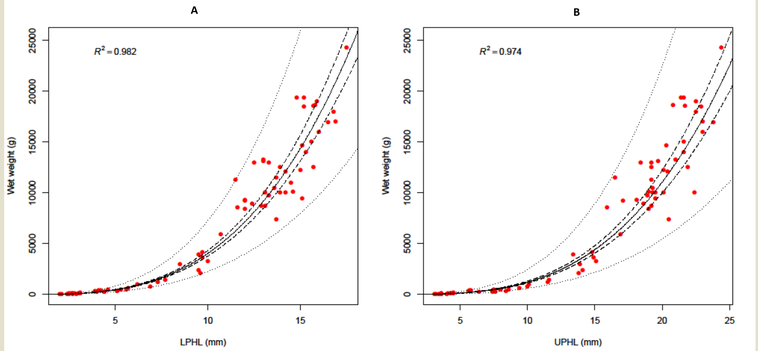

Figure 2. Relationship between pigmented hood length (mm) and octopus reconstructed mass (wet weight, g) for **(A)** lower beaks and **(B)** upper beaks. 95% CI (dashed line), 95% PI (dotted line).

- The regression used to calculate reconstructed mass was developed for the Alaskan octopus complex (Buckley et al., 2011), and was updated for the present study with measurements from additional octopus specimens (**Fig 2**).
- If pigmented hood lengths were obtainable for both beaks from a single octopus prey, the mean of the two reconstructed mass estimates was used.
- A one-tailed Wilcoxon-Mann-Whitney test was used to evaluate the difference in size distribution between octopus consumed by Pacific cod and octopus caught in bottom trawls.

References

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Results and Conclusions

- Pacific cod predation on octopus was most frequent in deeper water, on the outer EBS shelf, and was highest in the northwestern part of the survey area across all predator sizes (**Fig 3**).
- Octopus frequency of occurrence was 3% across all non-empty Pacific cod stomachs, and increased with predator size to about 6% among 60-99 cm Pacific cod (**Fig 3 inset**).
- The mean reconstructed mass from 2006 and 2009-2011 was 145.179 g, range 0.017–4662.462 g (n = 168).
- Most smaller octopus preyed upon in the northwestern survey areas (**Fig 4**) could be juvenile *Enteroctopus dofleini*, the dominant EBS shelf species, but also *Benthoctopus leioderma* along the EBS shelf edge or *Benthoctopus sibiricus* in the northernmost shallow waters of the EBS shelf (Jorgensen, 2009).

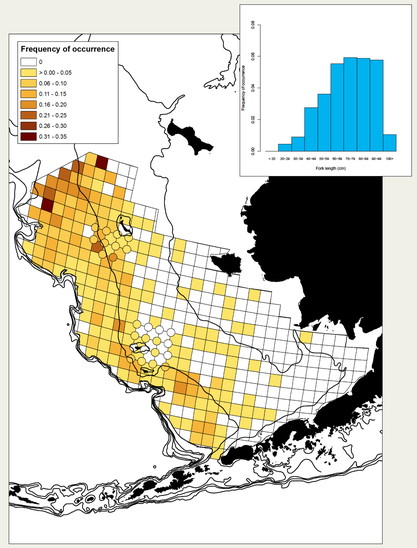

Figure 3. Prey octopus frequency of occurrence in Pacific cod stomachs across standard Alaska Fisheries Science Center EBS shelf bottom-trawl survey grid, years 1981-2011. Inset: octopus prey frequency of occurrence by predator fork length (cm), 1981-2011.

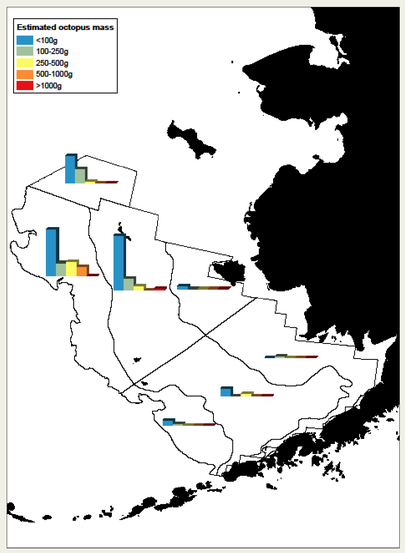

Figure 4. Frequency distribution of reconstructed octopus prey mass (n = 168) in seven survey strata.

- There was a significant positive relationship between Pacific cod fork length and log-transformed reconstructed prey mass (**Fig 5**; $R^2 = 0.456$, $P < 0.001$).

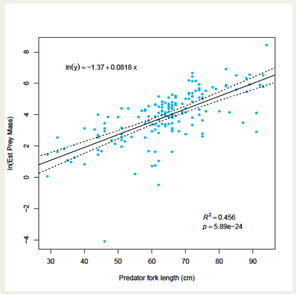

Figure 5. Linear regression between predator fork length (cm) and natural log of reconstructed octopus prey mass (g) with 95% confidence interval (dashed line). Years 2006 and 2009-2011, n = 168.

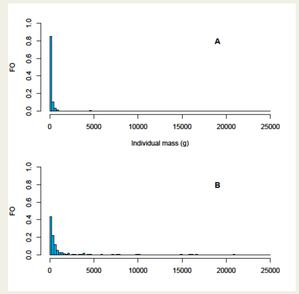

Figure 6. Individual octopus mass distribution from (A) Reconstructed masses in Pacific cod stomachs, years 2006 and 2009-2011 (n = 168) and (B) EBS shelf bottom-trawl surveys, years 2008-2011 (adapted from Conners et al., 2014; n = 269).

- The size distribution of octopus consumed by Pacific cod was skewed smaller than octopus from bottom-trawl surveys ($U_{0.05(1),168,269} = 11463$, $P < 0.001$), but modal mass was < 0.5 kg for both (**Fig 6**). Pacific cod predation is physiologically constrained by gape size, effectively excluding predation on larger octopus that are occasionally captured by bottom-trawl surveys (**Fig 6**).
- The spatial distribution of Pacific cod predation on octopus across the EBS shelf likely reflects the spatial distribution of smaller octopus in the bottom-trawl survey area.