W9: Puffins as Samplers of Forage Nekton in the North Pacific

PICES 2024, Honolulu, Hawaii

26 October 2024

Workshop Goals and Agenda

Introduction (William Sydeman, Farallon Institute)

1. Present information on puffins as samplers of forage nekton in the North Pacific (Yutaka Watanuki – Hokkaido University)
2. Present information on analytical and statistical issues facing researchers using puffins (predators) as samplers of forage nekton (Jim Thorson, NOAA)
3. Present information on a key, but poorly known forage fish in North Pacific food webs, Pacific Sand Lance, and how puffins and other predators can be used to better understand PSL population dynamics (Matt Baker, NPRB)
4. Present information on the use of puffin sampling in the study and management of Sablefish (Mayumi Arimitsu, USGS).
5. Discussion – a) opportunities, challenges; b) review paper

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Rhinoceros Puffin (Auklet)

Why Study Puffins to Study Forage Nekton?

1. North Pacific forage nekton: key to trophic transfer, diverse assemblage, very difficult/expensive to sample and study.
2. Puffins (3 spp. in Pacific) forage within ~50-100km of colonies (shelf/shelf break habitats), obtain forage nekton and bring them back to the colonies ("central place foraging") where they can be sampled by researchers (sampling relatively easy, without undue impact on the birds).
3. Large samples of fresh, whole fish can be obtained for morphometric, compositional, and genetic analyses.
4. Long-term spatially-comprehensive datasets on puffin-sampled forage nekton are available for analysis and insight.

Horned Puffin

5. Samples contain species (e.g. Pacific sand lance, capelin) and/or age classes (e.g., age-0 gadids/hexagrammids) that are difficult to sample by conventional means.

6. Samples are interpretable relative to changes in ocean conditions and climate.

7. Sample data has application(s) in both seabird and fisheries management and conservation.

8. Similar puffin sampling data is available in the Atlantic for ecosystem to hemispheric-scale comparative investigations.

Tufted Puffin


Atlantic Puffin
Fratercula arctica
11.4 inches, 19.4 oz
Horned Puffin
Fratercula corniculata
13 inches, 23 oz
Tufted Puffin
Fratercula cirrhata
15.8 inches, 35 oz
Rhinoceros Auklet
Cerorhinca monocerata
11 inches, 22 oz
Smithsonian
OCEAN
FIND YOUR BLUE

What Makes Puffins Such Great Samplers?
(Samples May Contain Multiple Fish)

Morphological Adaptation for Multiple Prey Items in Samples

Puffins hold fish with denticles in the back of their mouth with their tongue while they can continue to forage, resulting in multiple fish in each sample (this also presents analytical challenges though)

Table 1. Species contained within the 16 prey groups observed at the sites in this study.

Prey Group	Prey Species	Prey Common Name
Capelin	*Mallotus villosus*	Capelin
Flatfish	*Atheresthes stomias* (71%)	Arrowtooth flounder
	Pleuronectiformes	Flatfish
	Pleuronectidae	Right-eyed flatfish
	Hippoglossoides elassodon (18%)	Flathead sole
	Reinhardtius hippoglossoides (6%)	Greenland turbot
	Hippoglossus stenolepis (5%)	Pacific halibut
	Lepidopsetta spp.	Rock sole
	Glyptocephalus zachirus (<1%)	Rex sole
	Limanda spp.	Limanda spp.
Gadid	*Gadus chalcogrammus* (90%)	Walleye pollock
	Gadidae	Gadid
	Gadus macrocephalus (9%)	Pacific cod
	Microgadus proximus (<1%)	Pacific tomcod
	Eleginus gracilis (<1%)	Saffron cod
Hexagrammid	Hexagrammidae	Greenling
	Hexagrammos decagrammus (82%)	Kelp greenling
	Pleurogrammus monopterygius (17%)	Atka mackerel
	Hexagrammos lagocephalus (<1%)	Rock greenling
	Hexagrammos octogrammus (<1%)	Masked greenling
	Hexagrammos stelleri (<1%)	White-spotted greenling
Lingcod	*Ophiodon elongatus*	Lingcod
Mesopelagic	Myctophidae	Lanternfish
	Stenobrachius leucopsarus (86%)	Northern lampfish
	Stenobrachius nannochir (14%)	Garnet lampfish
Octopus	Octopoda	Octopus
	Octopodidae	Octopus
Pacific herring	*Clupea pallasii*	Pacific herring
Pacific sand lance	*Ammodytes personatus*	Pacific sand lance
Pacific sandfish	*Trichodon trichodon*	Pacific sandfish
Prowfish	*Zaprora silenus*	Prowfish
Rockfish	Scorpaenidae	Rockfish
	Sebastes spp.	Sebastes rockfish
	Sebastes aleutianus (42%)	Rougheye rockfish
	Sebastes melanops (47%)	Black rockfish
	Sebastes jordani (11%)	Shortbelly rockfish
Sablefish	*Anoplopoma fimbria*	Sablefish
Salmon	*Oncorhynchus* spp.	Salmon
	Oncorhynchus gorbuscha (72%)	Pink salmon
	Salmonidae	Salmonid
	Oncorhynchus nerka (7%)	Sockeye salmon
	Oncorhynchus tshawytscha (5%)	Chinook salmon
	Oncorhynchus keta (16%)	Chum salmon
	Oncorhynchus kisutch (<1%)	Coho salmon
Sculpin	Cottidae	Sculpin
	Phallocottus obtusus (60%)	Spineless sculpin
	Hemilepidotus jordani (19%)	Yellow Irish lord
	Hemilepidotus hemilepidotus (17%)	Red Irish lord
	Hemilepidotus spp.	Irish lord
	Icelus spiniger (<1%)	Thorny sculpin
	Triglops forficatus (<1%)	Scissortail sculpin
	Triglops pingelii (2%)	Ribbed sculpin
	Triglops spp.	Triglops sp.
	Psychrolutes paradoxus (1%)	Tadpole sculpin
	Blepsias bilobus (<1%)	Crested sculpin
	Blepsias cirrhosus (<1%)	Silver-spotted sculpin
	Hemitripterus bolini (<1%)	Bigmouth sculpin
	Nautichthys oculofasciatus (<1%)	Sailfin sculpin
Squid	Decabrachia	Squid
	Gonatidae	Squid
	Cephalopoda:Gonatidae	Squid
	Gonatus kamtschaticus (96%)	Squid
	Berryteuthis magister (2%)	Squid
	Gonatopsis makko (2%)	Squid

The percentage of each species in each group (of fish identified to the species level) is shown in parentheses.

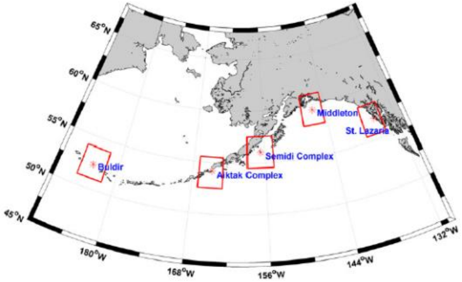
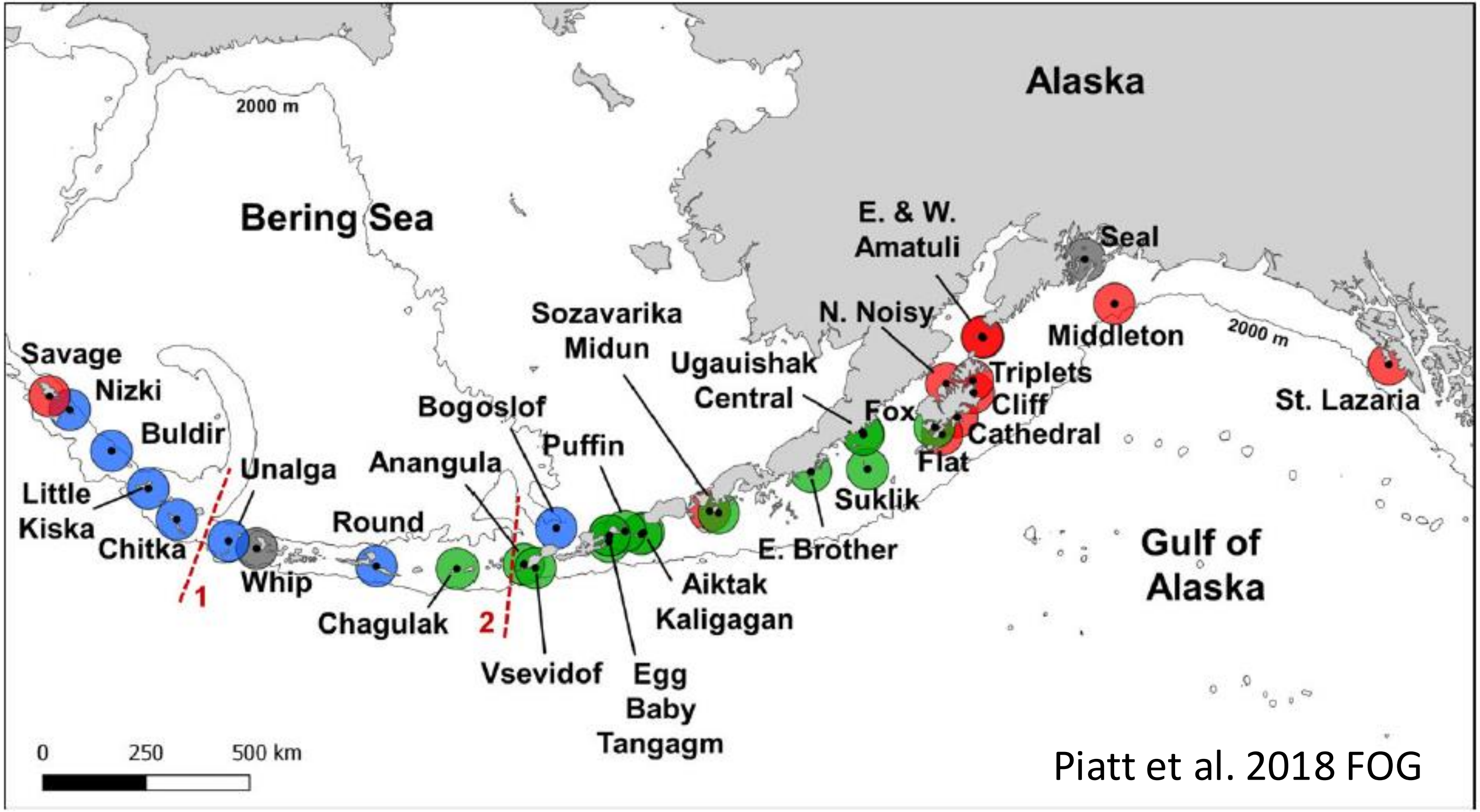


Table 2. Characteristics of the time series used in this study.

Island	Complex	Puffin	Time Series	No. Years Data	Latitude	Longitude
Buldir		TUPU	1988–2012	22	52.36	175.92
		HOPU	1988–2012	21		
Aiktak	Aiktak	TUPU	1986–2012	24	54.19	−164.84
Kaligagan			2012	1	54.15	−164.91
Round			2012	1	54.20	−164.78
Baby			2012	1	53.99	−166.07
Tangagm			1986	1	54.00	−166.06
Puffin			1991–2012	5	54.15	−165.53
Chowiet	Semidi	RHAU	1979–2012	11	56.03	−156.70
Suklik		TUPU	1979–1995	9	56.05	−156.64
		HOPU	1979–1995	9		
Middleton		TUPU	1978–2012	23	59.44	−146.33
		RHAU	1978–2012	23		
St. Lazaria		RHAU	1994–2012	19	56.99	−135.70

Puffins: tufted puffin (TUPU), horned puffin (HOPU), and rhinoceros auklet (RHAU).

Sydeman et al. 2017 FOG



Piatt et al. 2018 FOG

FIGURE 1 Colonies of tufted puffins in Alaska (black dots) where diet samples were collected. Colonies are ringed with a colored circle (50 km radius) in which habitat characteristics were measured. Colors represent different diet community types and were assigned by cluster analysis of diet composition (Red—Coastal residents; Green—Shelf transients; Blue—Oceanic; see text for details). Two passes in the Aleutian Islands are indicated by red dashed lines: (1) Amchitka Pass and (2) Samalga Pass

Some Key Literature

Hatch, S. A., & Sanger, G. A. (1992). Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. *Marine Ecology Progress Series*, *80*, 1–14.

Thayer, J. A., Bertram, D. F., Hatch, S. A., Hipfner, M. J., Slater, L., Sydeman, W. J., & Watanuki, Y. (2008). Forage fish of the Pacific Rim as revealed by diet of a piscivorous seabird: synchrony and relationships with sea surface temperature. *Canadian Journal of Fisheries and Aquatic Sciences*, *65*, 1610–1622. https://doi.org/10.1139/F08-076

Sydeman, W. J., Piatt, J. F., Thompson, S. A., García-Reyes, M., Hatch, S. A., Arimitsu, M. L., Slater, L., Williams, J. C., Rojek, N. A., Zador, S. G., & Renner, H. M. (2017). Puffins reveal contrasting relationships between forage fish and ocean climate in the North Pacific. *Fisheries Oceanography*, *26*, 379–395. https://doi.org/10.1111/fog.12204

Piatt, J. F., Arimitsu, M. L., Sydeman, W. J., Thompson, S. A., Renner, H., Zador, S., Douglas, D., Hatch, S., Kettle, A., & Williams, J. (2018). Biogeography of pelagic food webs in the North Pacific. *Fisheries Oceanography*, *27*, 366–380. https://doi.org/10.1111/fog.12258

Thompson, S. A., Garcia-Reyes, M., Sydeman, W. J., Arimitsu, M. L., Hatch, S. A., & Piatt, J. F. (2019). Effects of ocean climate on the length and condition of forage fish in the Gulf of Alaska. *Fisheries Oceanography*, *28*, 658–671. https://doi.org/10.1111/fog.12443

DOI: 10.1111/faf.12611

FISH and FISHERIES WILEY

ORIGINAL ARTICLE

Integrating seabird dietary and groundfish stock assessment data: Can puffins predict pollock spawning stock biomass in the North Pacific?

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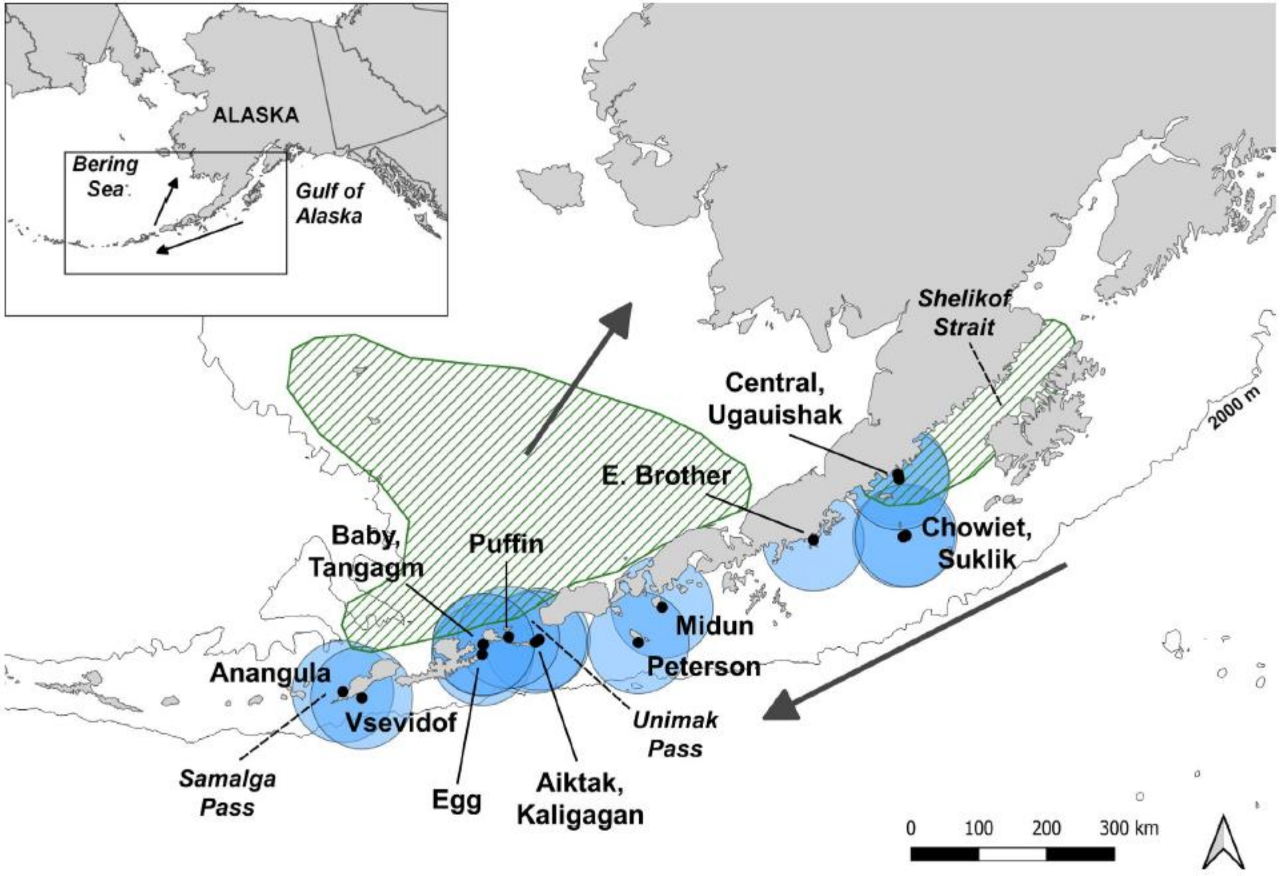


FIGURE 1 Map showing 15 sites in the Western Gulf of Alaska where age-0 gadids were sampled by puffins over 31 years, 1985–2015. A 75-km foraging/sampling radius for the birds is shown for each site. Approximate walleye pollock spawning regions in the Shelikof Strait area and Eastern Bering Sea are shown as green hatched areas (based on Bacheler et al. 2009, 2010; Hinckley et al., 2016). Larval pollock produced in/near Shelikof Strait are advected along the Alaska Peninsula and through Unimak Pass (Hinckley, 1987; Parada et al., 2016) where Aiktak Island is located. The 2000-m isobath is shown for context

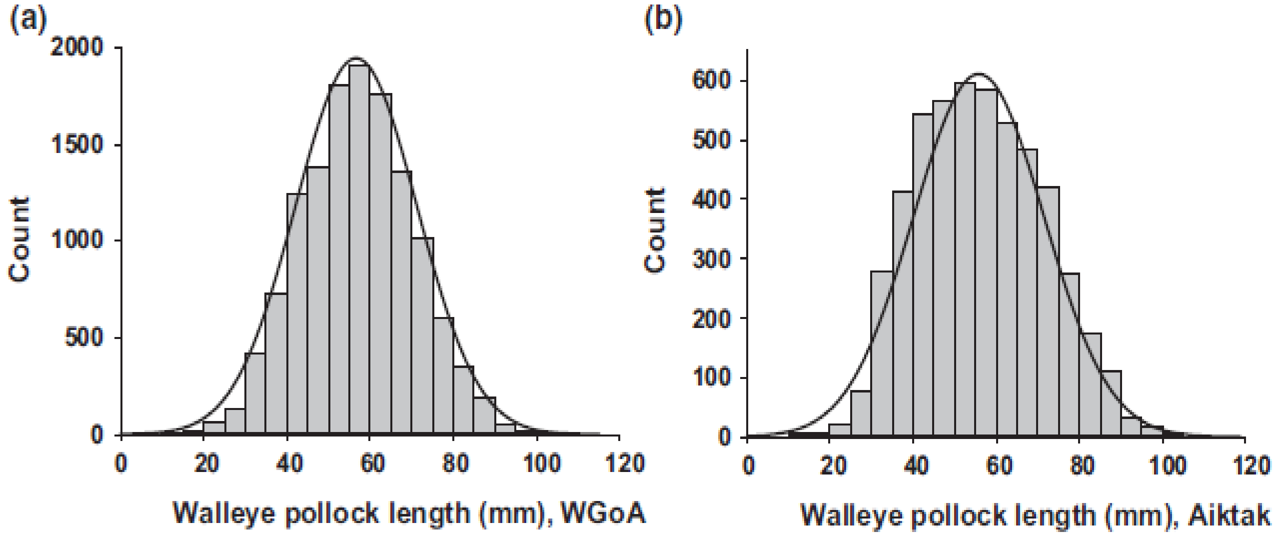
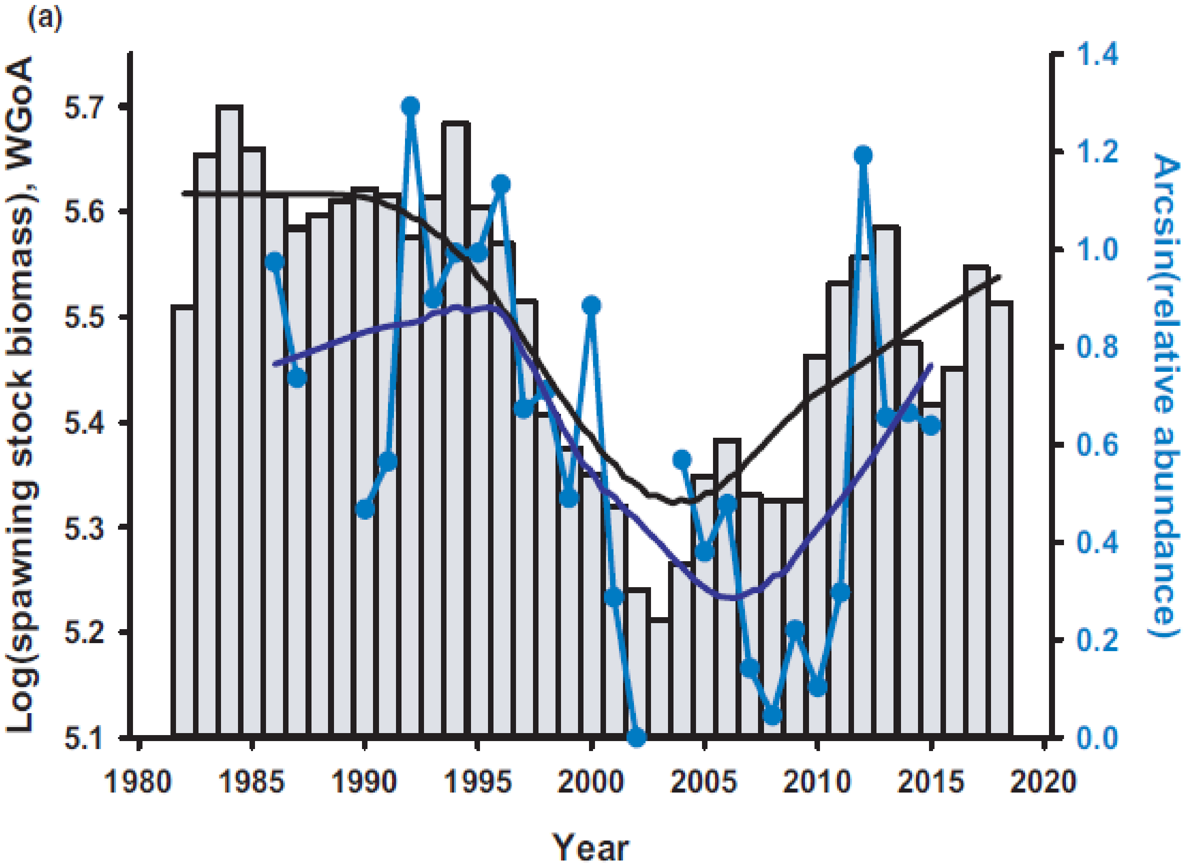


FIGURE 2 (a) Length-frequency distribution with normal distribution curve across all years for walleye pollock 0–120 mm in length at WGoA sites; 23 fish longer than 120 mm are not shown. (b) Length-frequency distribution with normal distribution curve across all years at Aiktak Island for fish 0–120 mm in length; 4 fish longer than 120 mm are not shown. (c) Growth index anomalies for walleye pollock over 16 years based on a linear regression of length by date within each year for all sites in the WGoA and Aiktak Island alone. Dashed lines show ± 1 *SD* for the WGoA data. Years without bars reflect no data

FIGURE 3 Pollock spawning stock biomass (bars) and age-0 abundance index at Aiktak Island (points) through time, with Loess smoothing lines (black, biomass; blue, age-0 abundance). (a) WGoA SSB and (b) EBS SSB



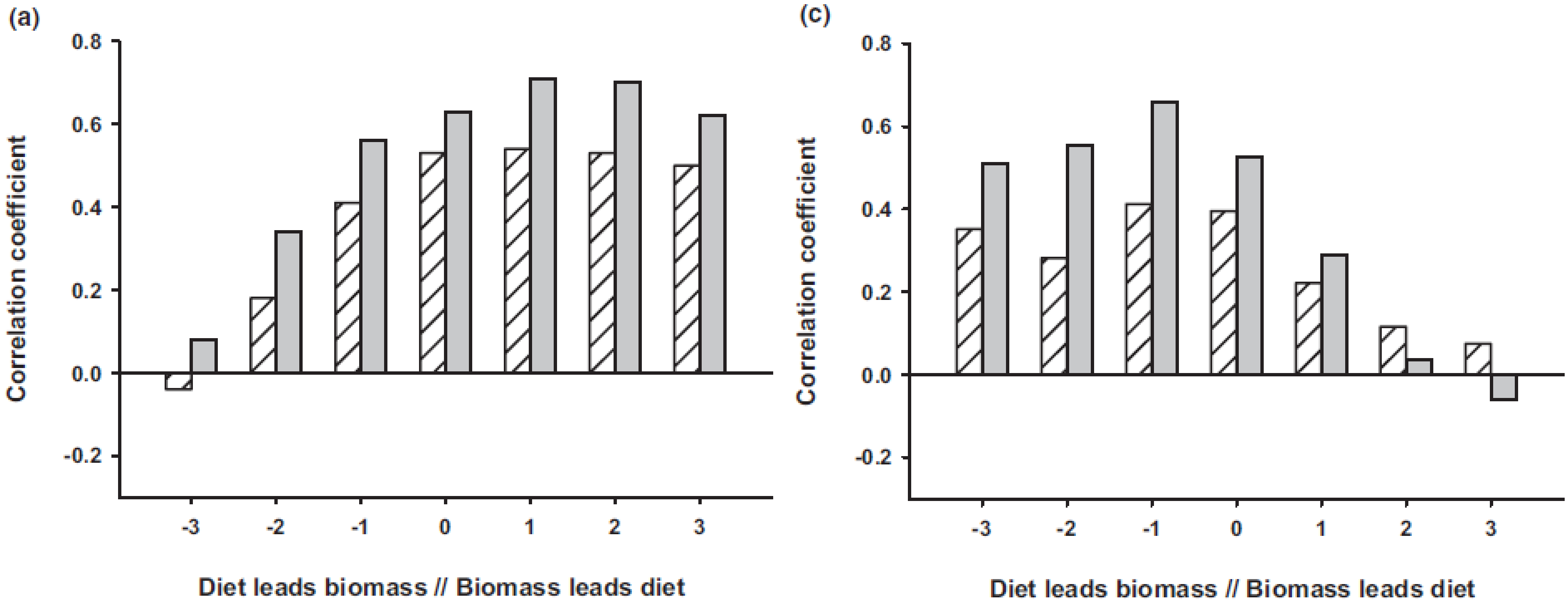
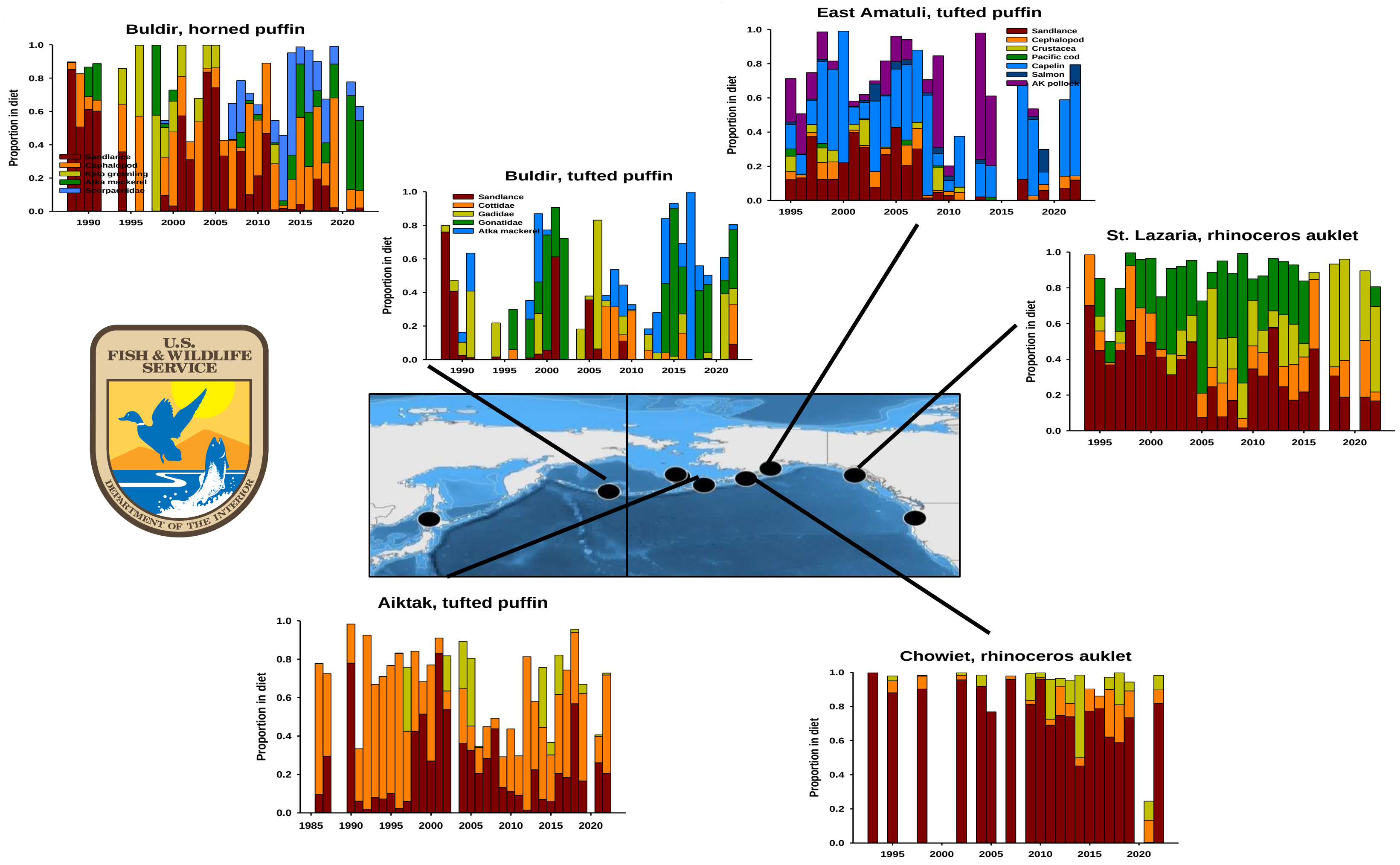


FIGURE 4 Spearman rank cross-correlations between SSB and age-0 abundance or growth from all WGoA sites or Aiktak Island alone. (a) WGoA SSB vs. age-0 abundance, (b) WGoA SSB and growth, (c) EBS SSB and age-0 abundance, and (d) EBS SSB and growth. Spearman ρ is shown on the y-axis, and lags/leads of up to 3 years are shown on the x-axis. Negative lags indicate age-0 abundance or growth leading SSB, while positive values indicate SSB leading age-0 abundance or growth. WGoA correlations are hatched bars, while Aiktak correlations are grey bars. Significance (p-value) of the correlations is shown by asterisks: *≤.1, **≤.01, and ***≤.001. Regressions of key selected key relationships are shown in Table 2, with corresponding scatter-plots of relationships in Figure 5

TABLE 2 Linear regressions for Aiktak Island age-0 abundance or growth against WGoA or EBS SSB

Model description	*N*	*F*	*p* > F	R^2	Coefficient	t	*p* > |t|
Can SSB predict age-0 abundance?							
WGoA SSB and age-0 abundance, no lead/lag	27	18.61	.000	.43	0.2377	4.31	<.001
WGoA SSB leads age-0 abundance by 1 year	27	23.48	.001	.48	1.8100	4.85	<.001
Can age-0 abundance predict SSB?							
Age-0 abundance leads EBS SSB by 1 year	27	17.03	.000	.41	0.1949	4.13	<.001
Age-0 abundance leads EBS SSB by 2 years	27	9.67	.005	.28	0.1611	3.11	.005
Age-0 abundance leads EBS SSB by 3 years	27	6.36	.018	.20	0.1324	2.52	.018
Can growth predict SSB?							
Growth leads EBS SSB by 3 years (all years)	14	2.67	.128	.18	0.1184	1.63	.128
Growth leads EBS SSB by 3 years (2009 outlier removed)	13	12.30	.005	.53	0.1046	3.51	.005

Note: Shading indicates nominal significance of $p < .05$.


Buldir, horned puffin
Proportion in diet
1.0
0.8
0.6
0.4
0.2
0.0
1990
1995
2000
2005
2010
2015
2020
Sandlance
Cephalopod
Kelp greenling
Atka mackerel
Scorpaenidae
Buldir, tufted puffin
Proportion in diet
Sandlance
Cottidae
Gadidae
Gonatidae
Atka mackerel
East Amatuli, tufted puffin
Proportion in diet
Sandlance
Cephalopod
Crustacea
Pacific cod
Capelin
Salmon
AK pollock
St. Lazaria, rhinoceros auklet
Proportion in diet
U.S.
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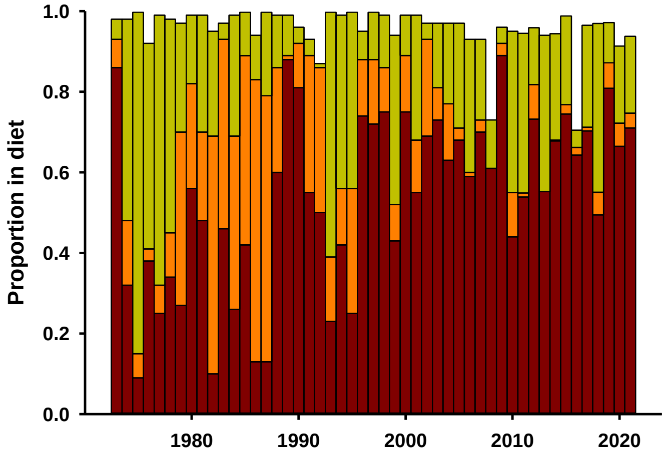
Aiktak, tufted puffin
Proportion in diet
1985
Chowiet, rhinoceros auklet
Proportion in diet

North Atlantic Data

North Sea

Isle of May, Atlantic puffin



Norwegian Sea

Röst, Atlantic puffin