Spatial and temporal trends in the abundance and distribution of groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016

Author and contact author: Ellen Yasumiishi, Kristin Cieciel, Alex Andrews, Elizabeth Siddon, Auke Bay Laboratories, AFSC, NOAA, 17109 Pt. Lena Loop Rd. Juneau AK 99801. Ellen.yasumiishi@noaa.gov
Last updated: June 2017

Description of index: Pelagic fish and jellyfish were sampled using a trawl net towed in the upper 20 m of the eastern Bering Sea during the Alaska Fisheries Science Centers' Bering Arctic Subarctic Integrated Surveys (BASIS) during late summer, 2002-2016. Stations were approximately 30 nautical miles apart and a trawl was towed for approximately 30 minutes. Area swept was estimated from horizontal net opening and distance towed.

Fish catch was estimated in kilograms. Surveys were not conducted in the south (<60 °N) during 2013 and 2015 and north (≥60 °N) during 2008 but fish densities in these areas were estimated using geostatistical modeling methods (Thorson et al. 2015). Four species were commonly caught with the surface trawl: age-0 Pacific cod (*Gadus macrocephalus*), age-0 pollock (G*adus chalcogrammus*), Atka mackerel (*Pleurogrammus monopterygius*), and yellowfin sole (*Limanda aspera*). Biomass was calculated for each species and compared across species and oceanographic domains on the Bering Sea shelf.

Abundance and distribution (center of gravity and area occupied) were estimated for each jellyfish species using the VAST package for multispecies version 1.1.0 (Thorson 2015; Thorson et al. 2016a, b, c) in RStudio version 0.99.896 and R software version 3.3.0 (R Core Team 2016). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016a, 2016b, 2016c) to estimate indices of abundance for stock assessments. We specified a gamma distribution and estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components at a spatial resolution of 100 knots. Parameter estimates were within the upper and lower bounds.

Abundance and distribution (center of gravity and area occupied) were estimated for using the VAST package for multispecies version 1.1.0 (Thorson 2015; Thorson et al. 2016a, b, c) in RStudio version 0.99.896 and R software version 3.3.0 (R Project 2017). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016) to estimate indices of abundance for stock assessments. We specified a gamma distribution and estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components at a spatial resolution of 100 knots. Parameter estimates were within the upper and lower bounds and final gradients were less than 0.0005.

Status and trends: Temporal trends in the estimated abundance of these groundfish species indicated a decline in the productivity of groundfish in pelagic waters of the eastern Bering Sea in 2016 (Figure 1-5, Table 1). Juvenile age-0 pollock were the most abundant juvenile pelagic groundfish species in our survey areas followed by yellow fin sole, Atka mackerel, and then Pacific cod (Table 1).

Distribution of groundfish in pelagic waters varied among species and years (Figure 2-5). Age-0 P. cod were distributed on the southern Bering Sea shelf near the Unimak Pass (Figure 2). Age-0 pollock were the most widely distributed species and primarily on the southeastern Bering Sea middle domain (50-100 m bottom depth) but distributed farther north during warm years (Figure 3). Atka mackerel were captured primarily in the outer domain of the southeastern Bering Sea shelf (Figure 4). Yellowfin sole distributed in the southern inner and middle domains of the southeastern Bering Sea shelf (Figure 5).

Temporal trends in the distribution (center of gravity) that age-0 pollock were distributed farther north during recent warm years (Figure 6). No warm and cold year trends was observed in the distribution of age-0 P. cod, yellowfin sole. Atka mackerel were generally distributed farther north during warm stanzas and farther south during the cold stanza (Figure 6). Area occupied indicated that pollock had an expanded range during warm years relative to cold years (Figure 7).

Factors causing trends: Lower abundances of groundfish in pelagic waters during 2016, third consecutive warm year, indicate poor environmental conditions for the growth and survival in the eastern Bering Sea during summer or movement out of the survey area. Age-0 pollock appeared to respond to warming with an expansion in their range and a distribution farther north. Movement of age-0 pollock and Atka mackerel farther north during warm years indicate a response to warming by their changing distribution.

Implications: Lower abundances of groundfish in surface waters during 2016 indicate a change in productivity in pelagic waters. The age-0 pollock distributed primarily in the southeastern Bering Sea middle domain, but were farther north during warm years during higher population densities possibly in search of food during years of low lipid-rich prey such as large zooplankton (Coyle et al. 2011).

Citations:

Coyle K.O., L.B. Eisner, F.J. Mueter, A.I. Pinchuk, M.A. Janout, K.D. Cieciel, E.V. Farley, and A.G. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. Fisheries Oceanography 20(2):139-56.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Thorson, J.T., A.O. Shelton, E.J. Ward, and H.J. Skaug. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science 72(5):1297-1310. doi:10.1093/icesjms/fsu243

Thorson, J.T., and K. Kristensen. 2016a. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. Fisheries Research 175:66-74. doi:10.1016/j.fishres.2015.11.016.
url: http://www.sciencedirect.com/science/article/pii/S0165783615301399

Thorson, J.T., M.L. Pinsky, and E.J. Ward. 2016b. Model-based inference for estimating shifts in species distribution, area occupied and centre of gravity. Methods in Ecology and Evolution 7(8):990-1002.

Thorson, J.T., A. Rindorf, J. Gao, D.H. Hanselman, and H. Winker. 2016c. Density-dependent changes in effective area occupied for sea-bottom-associated marine fishes. Proceedings of the Royal Society B 283(1840):20161853.

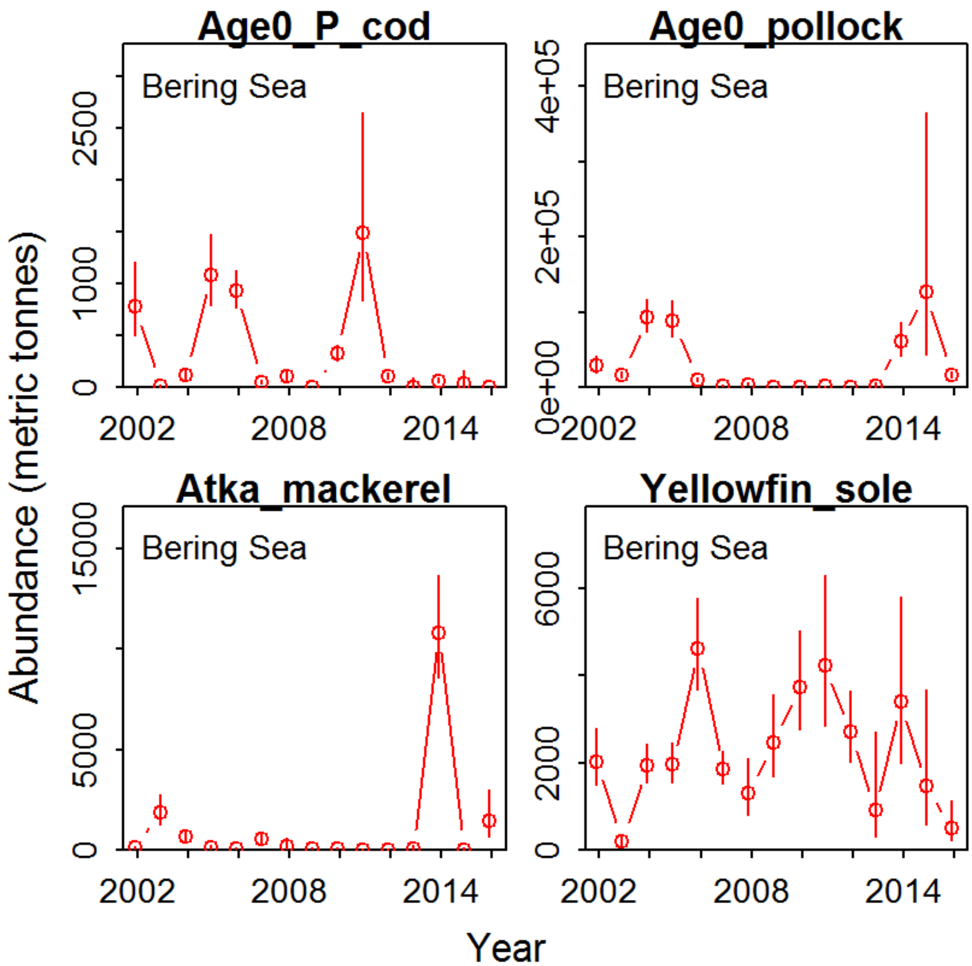

Figure 1. Index of abundance (metric tonnes) plus/minus 1 standard error for groundfish species in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

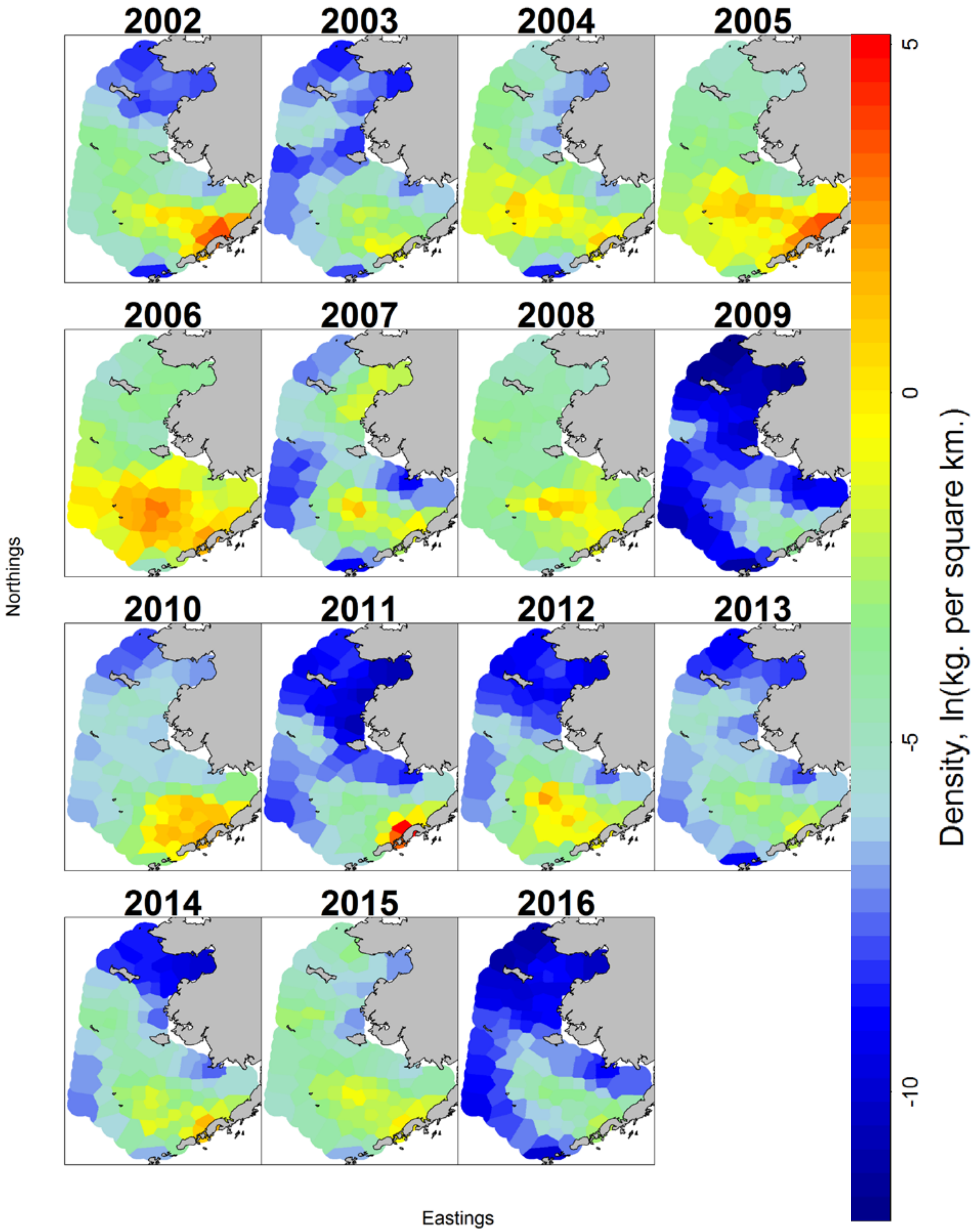

Figure 2. Predicted field densities of age-0 Pacific cod in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

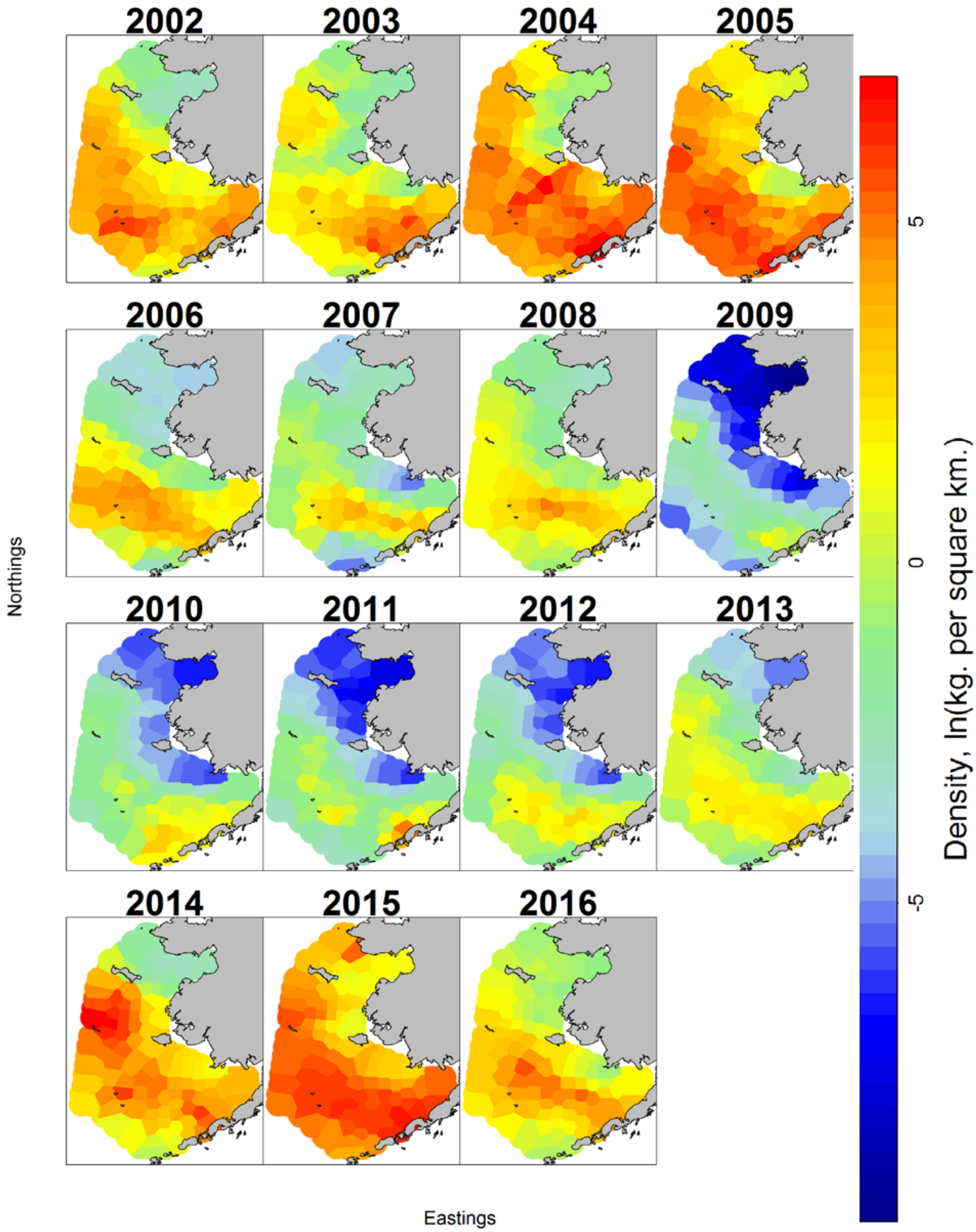

Figure 3. Predicted field densities of age-0 pollock in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

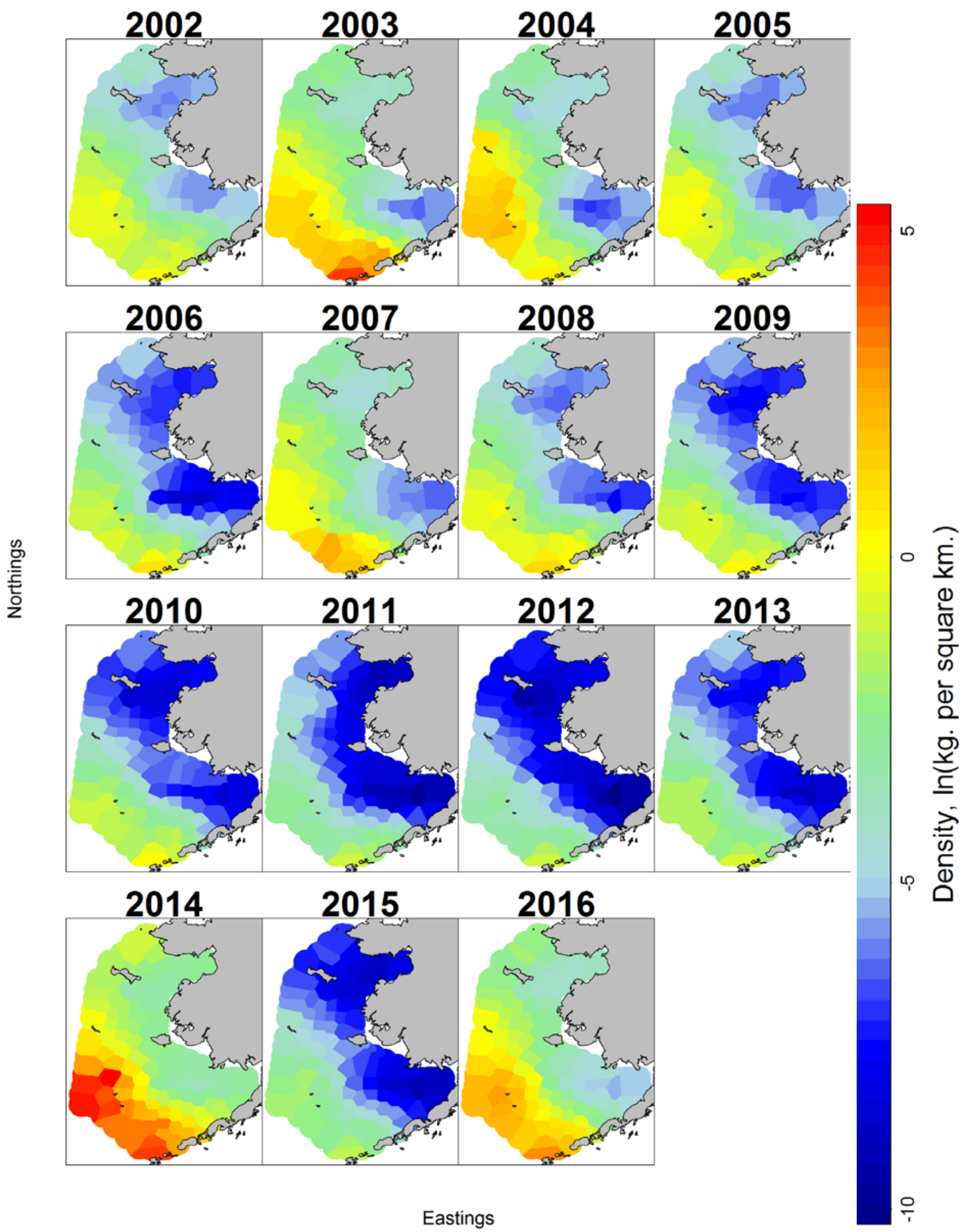

Figure 4. Predicted field densities of Atka mackerel in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

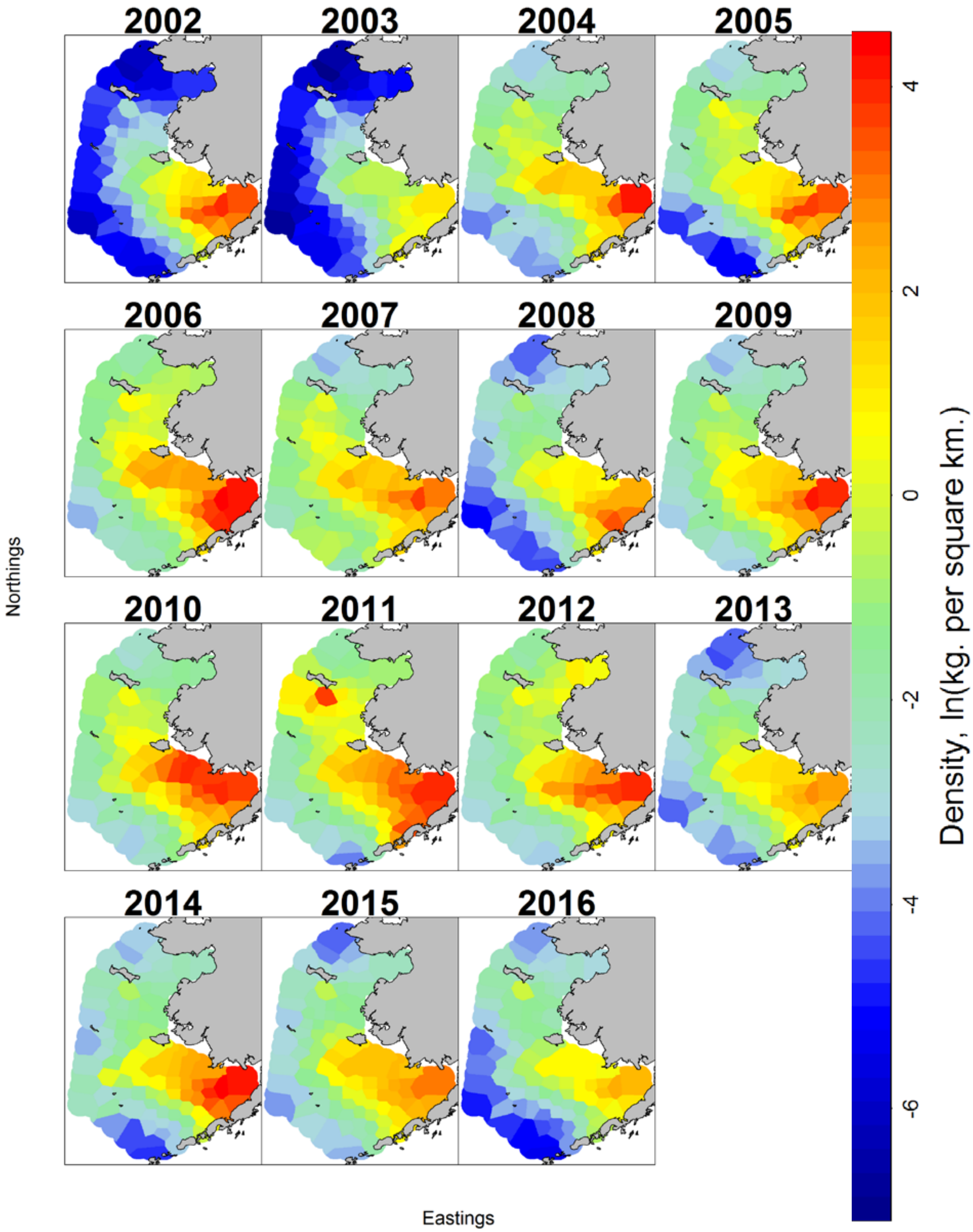

Figure 5. Predicted field densities of yellowfin sole in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

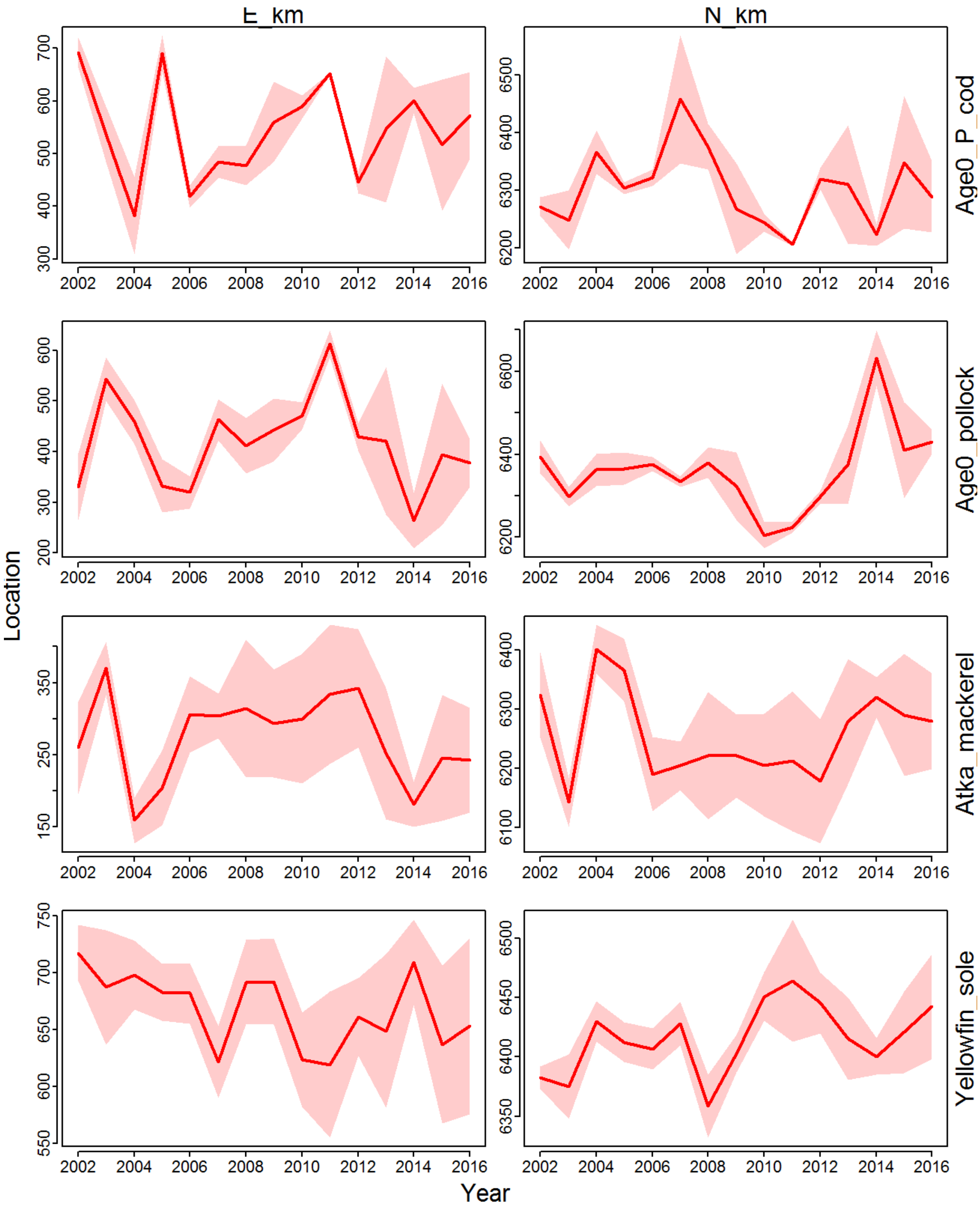

Figure 6. Center of gravity indicating temporal shifts in the mean east-to-west and north-to-south distribution plus/minus 1 standard error in UTM (km) for groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

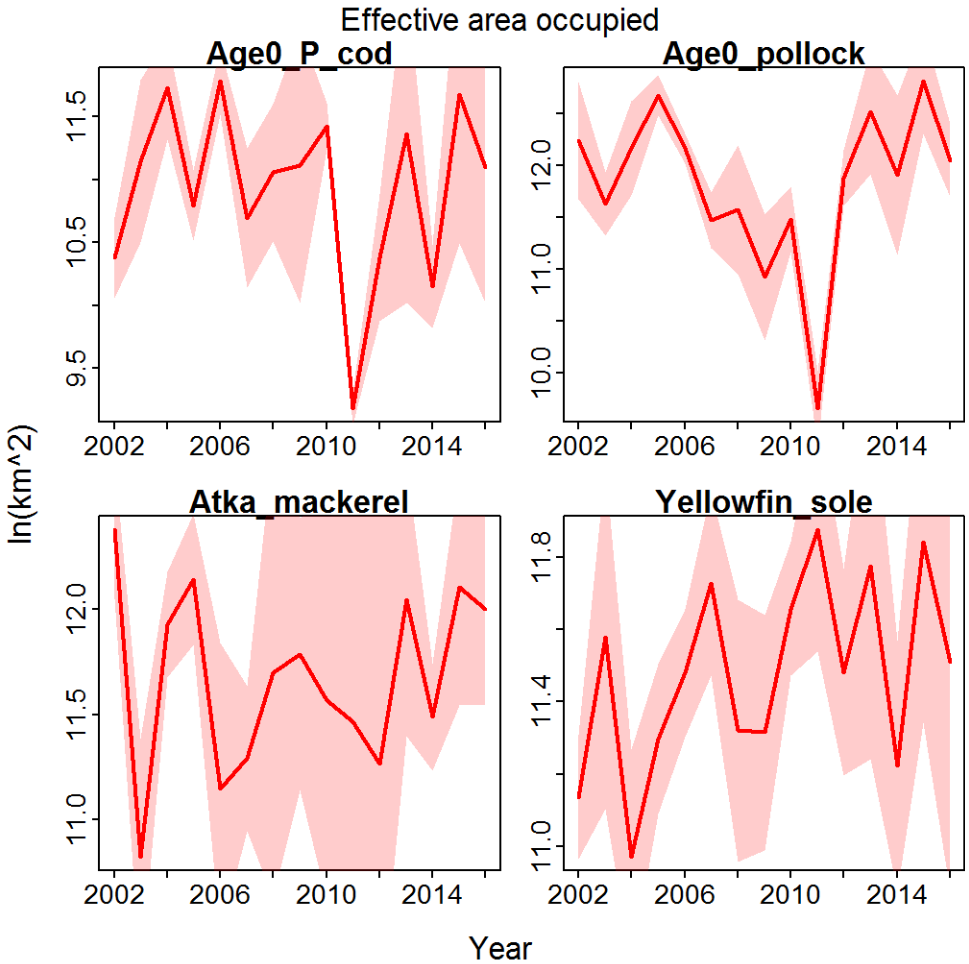

Figure 7. Effective area occupied (ln(km^2)) indicating range expansion/contraction plus/minus 1 standard error for groundfish in pelagic waters of the eastern Bering Sea shelf during late summer, 2002-2016.

Table 1. Index of abundance (metric tonnes) plus/minus 1 standard error (SE), and the coefficient of variation (%) for groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

	Age-0 P. cod			Age-0 pollock			Atka mackerel			Yellowfin sole		
	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.
2002	776	345	44%	28,989	10,705	37%	113	61	54%	2,028	644	32%
2003	15	10	69%	16,866	4,027	24%	1,857	733	39%	194	104	53%
2004	122	37	31%	92,590	21,439	23%	638	270	42%	1,928	439	23%
2005	1,086	335	31%	88,836	23,511	26%	125	65	52%	1,956	455	23%
2006	937	179	19%	10,371	2,076	20%	79	37	46%	4,608	1,042	23%
2007	51	15	28%	2,325	547	24%	529	193	36%	1,860	368	20%
2008	105	39	37%	4,254	1,587	37%	156	215	138%	1,308	623	48%
2009	1	1	118%	82	41	51%	72	47	66%	2,448	913	37%
2010	324	80	25%	809	259	32%	53	38	72%	3,724	1,107	30%
2011	1,490	856	57%	1,562	924	59%	15	18	122%	4,231	1,685	40%
2012	110	29	26%	751	150	20%	12	13	108%	2,706	815	30%
2013	9	21	238%	1,565	2,139	137%	29	63	221%	922	994	108%
2014	66	24	36%	60,583	22,268	37%	10,831	2,537	23%	3,393	1,820	54%
2015	36	54	152%	126,858	134,018	106%	18	33	181%	1,464	1,347	92%
2016	3	3	86%	16,437	4,358	27%	1,432	1,063	74%	493	407	83%
Mean	342	135	67%	30,192	15,203	44%	1,064	359	85%	2,218	851	46%