Spatial and temporal trends in the abundance and distribution of forage fish and squid in the eastern Gulf of Alaska during summer 2011-2016

Author and contact author: Jamal Moss, Wesley Strasburger, and Ellen Yasumiishi.
Auke Bay Laboratories, AFSC, NOAA, 17109 Pt. Lena Loop Rd. Juneau AK 99801.
jamal.moss@noaa.gov

Last updated: August 2017

Description of index: Pelagic fish were sampled using a trawl net towed in the upper 20 m of the eastern Gulf of Alaska during the Alaska Fisheries Science Center's Gulf of Alaska Assessment Surveys during summer, 2011-2016. Stations were approximately 10 nautical miles apart and a trawl was towed for approximately 30 minutes. The area swept by the trawl was estimated from horizontal net opening and distance towed.

Fish catch was estimated in kilograms by year and station. Forage fish and squid weight was estimated by multiplying the grand mean weight in a given year by the number captured at a station. Surveys were not conducted in waters of the continental shelf of the eastern Gulf of Alaska. Three forage species commonly captured in the trawl included: Pacific herring (*Clupea pallasii*), squid (*Gonadus, Berryteuhis*), and wolf eel (*Anarrhicthys ocellatus*).

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 1.0.136 and R software version 3.3.0 (R Core Team 2016a). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016a) 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: Pacific herring were most abundant in 2011 but have remained at low abundances in the GOA since 2012 (Figure 1). Wolf eel abundance was relatively low between 2011 and 2014, increased to the highest level observed in 2015, and then moderated to an intermediate level in 2016 (Figure 1; Table 1). Squid has steadily increased since 2011 with the exception of a large spike in abundance in 2014 (Figure 1; Table 1).

Distribution of these species varied by species and year. Herring distributed near shore (Figure 2). Wolf eel distributed offshore (Figure 3). Squid were distributed more evenly across the shelf (Figure 4). During the 2014-2016 warm years, squid were distributed farther north (Figure 5) and over a larger area (Figure 6). Herring and wolf eel did not show a distinct warm and cold year difference in their distributions.

Factors causing trends: Low abundance of herring and high abundance of wolf eel in pelagic waters during 2015 may be a response to atypically warm conditions. Herring were most abundant during 2011 when conditions were anomalously cool despite poor primary production (Strom et al. 2016) and an increased abundance of salps (Li et al. 2016), which further reduced

the amount of plankton available transfer energy to upper trophic levels. Squid abundance was lowest during 2011, and have been more negatively affected by poor primary production. Piscivorous predators not common to the eastern Gulf of Alaska were present in the eastern Gulf of Alaska during 2014, and 2015, presumably in response to unprecedented warming in the eastern Pacific Ocean commonly referred to as the 'Warm Blob' (Bond et al. 2015). Additional predation pressure by these warm water predators may have reduced the amount of forage fish that would have otherwise been present.

Implications: Lower abundances of herring in 2016 may have caused seabirds and adult salmon to prey upon squid or other alternative prey during 2016.

Citations:

Bond, N.A., M.F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters 42(9):3414-3420.

Li, K. A.J. Doubleday, M.D. Galbraith, and R.D. Hopcroft. 2016. High Abundance of salps in the Gulf of Alaska during 2011: A first record of bloom occurrence for the northern Gulf. Deep Sea Research Part II 132: 136-145.

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/.

Strom, S.L., K.A. Fredrickson, K.J. Bright. 2016. Spring phytoplankton in the eastern coastal Gulf of Alaska: Photosynthesis and production during high and low bloom years. Deep Sea Research II 132:107-121.

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.

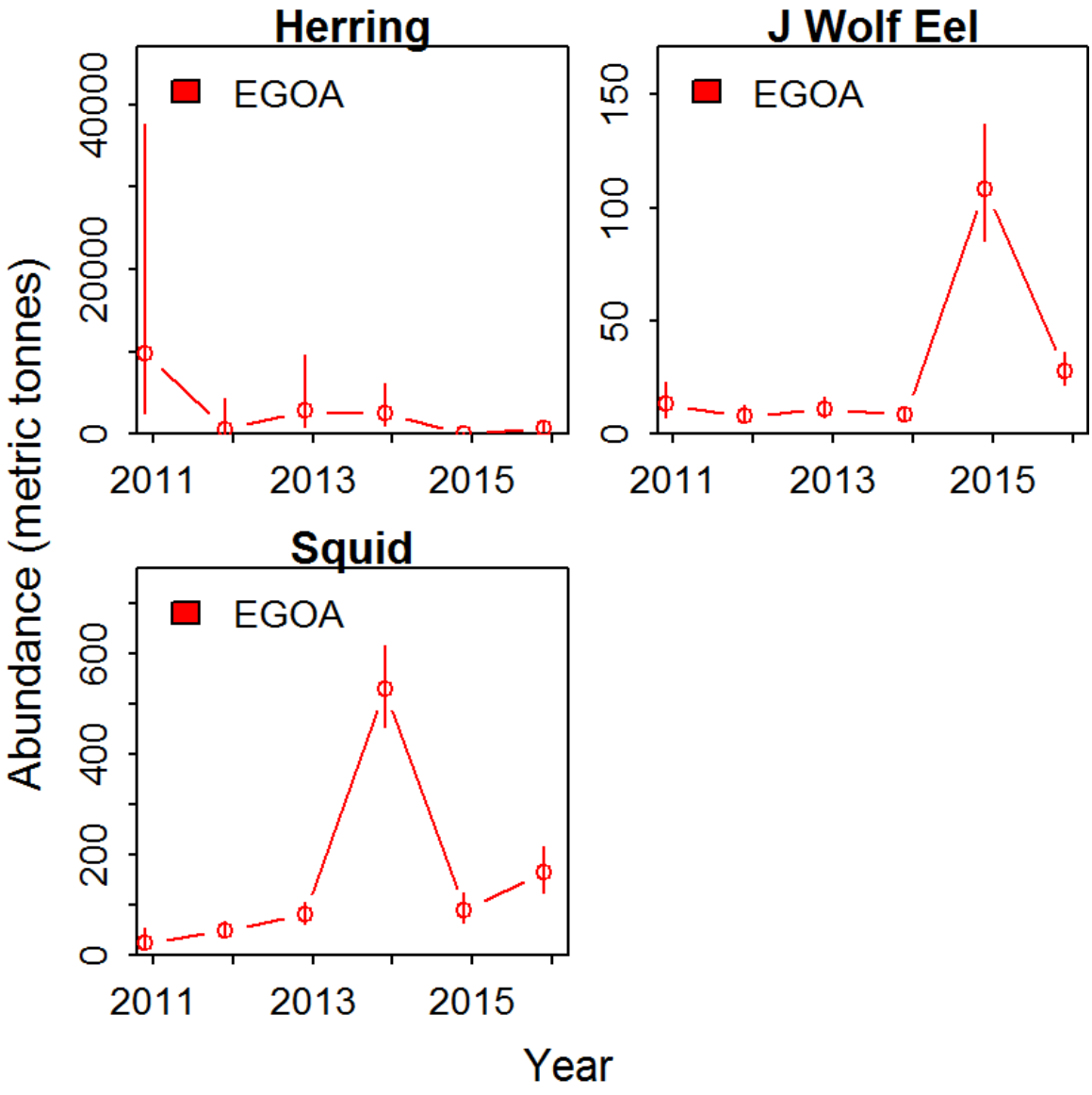

Figure 1. Index of abundance (metric tonnes) plus/minus 1 standard error for forage fish in the eastern Gulf of Alaska during late summer, 2011-2016.

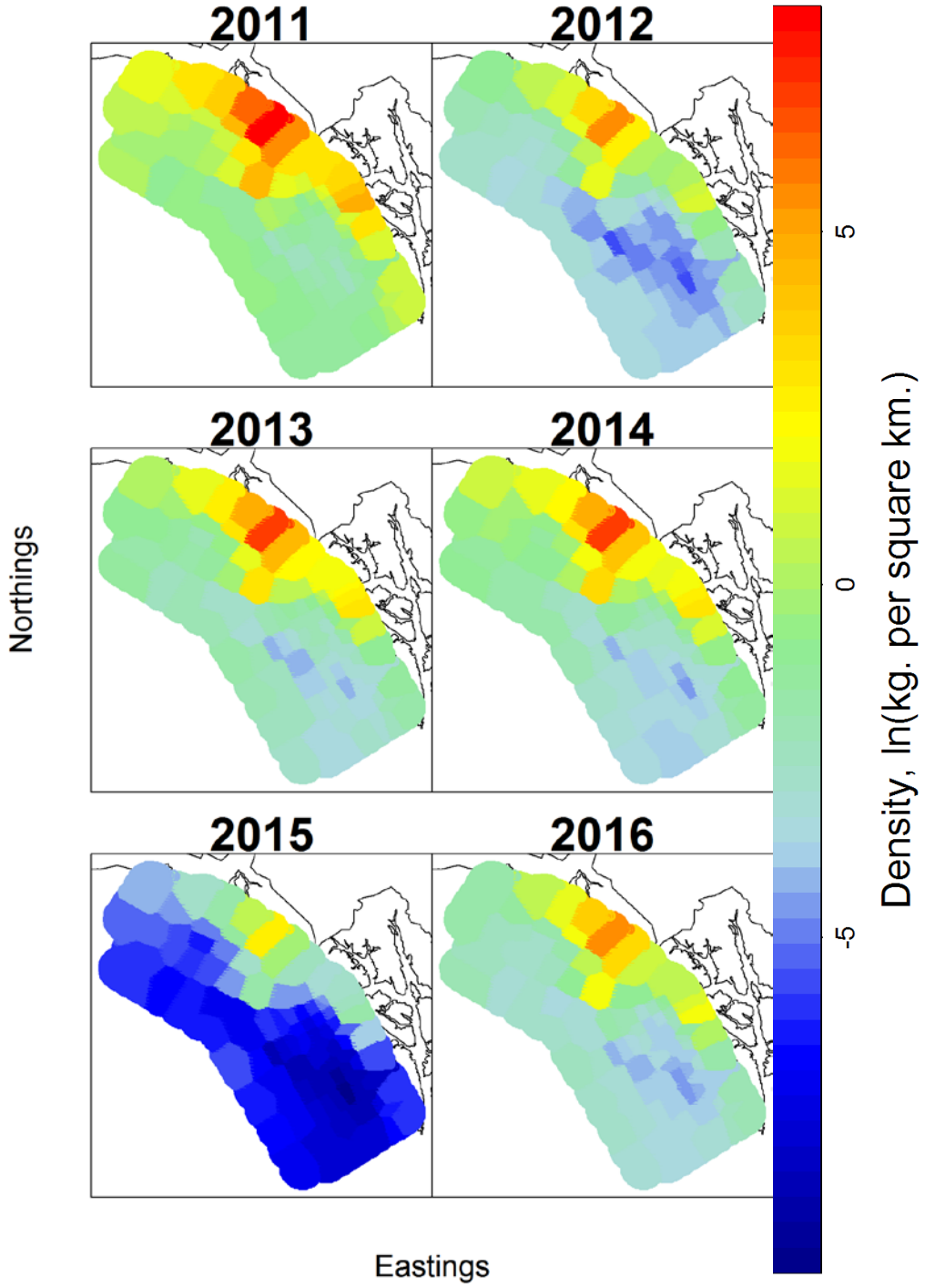

Figure 2. Predicted field densities of herring in the eastern Gulf of Alaska during summer, 2011-2016.

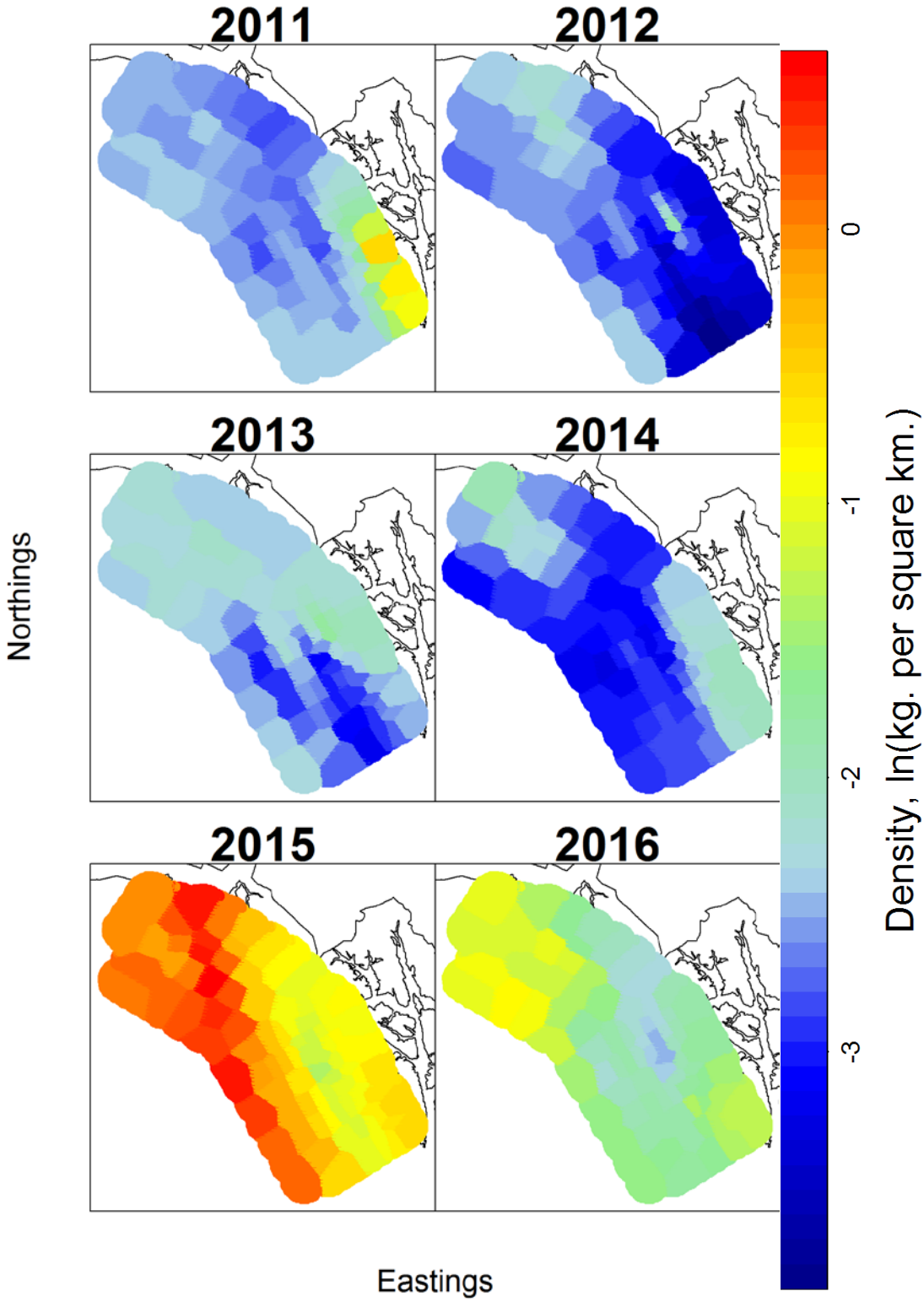

Figure 3. Predicted field densities of wolf eel in the eastern Gulf of Alaska during summer, 2011-2016.

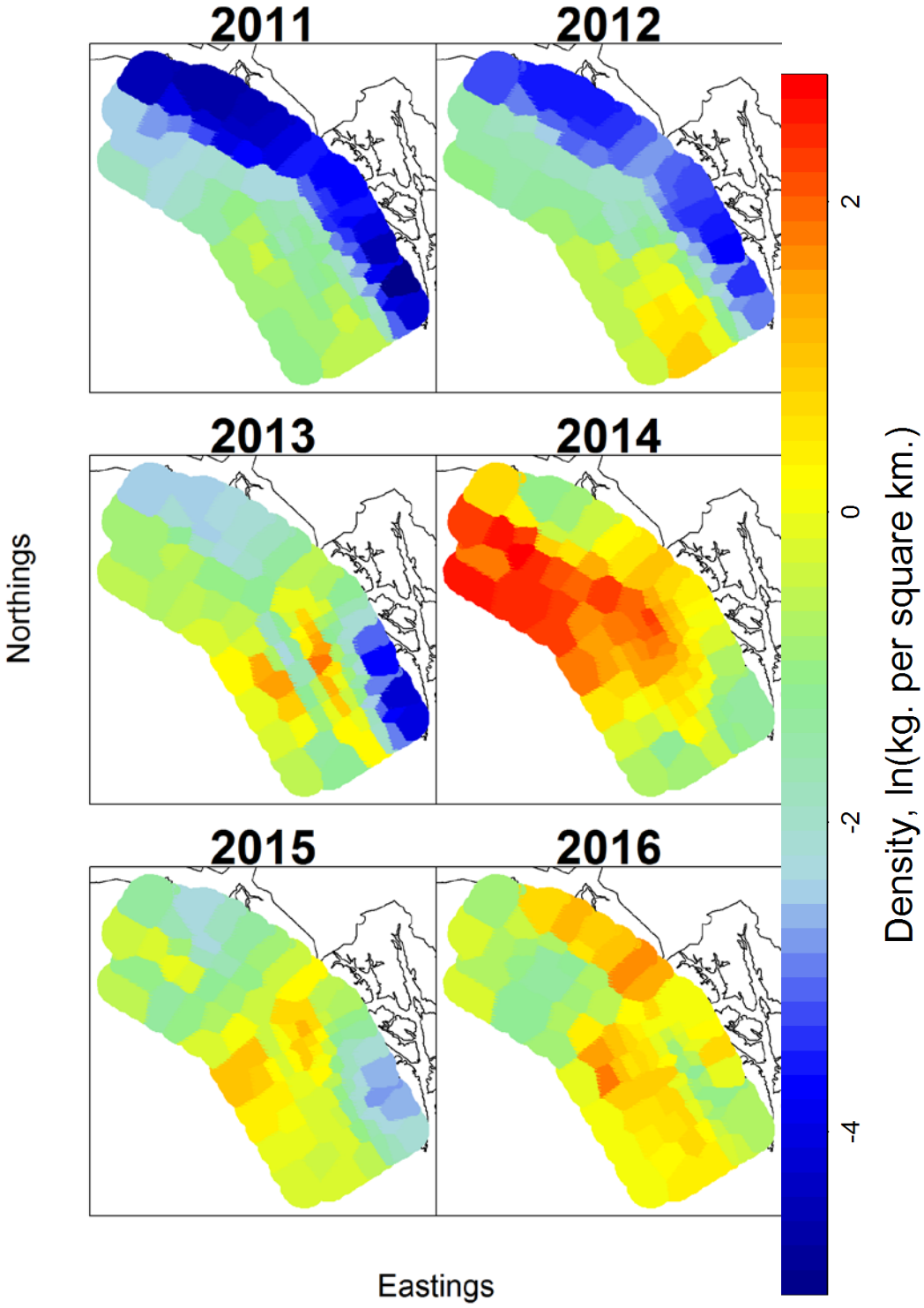

Figure 4. Predicted field densities of squid in the eastern Gulf of Alaska during summer, 2011-2016.

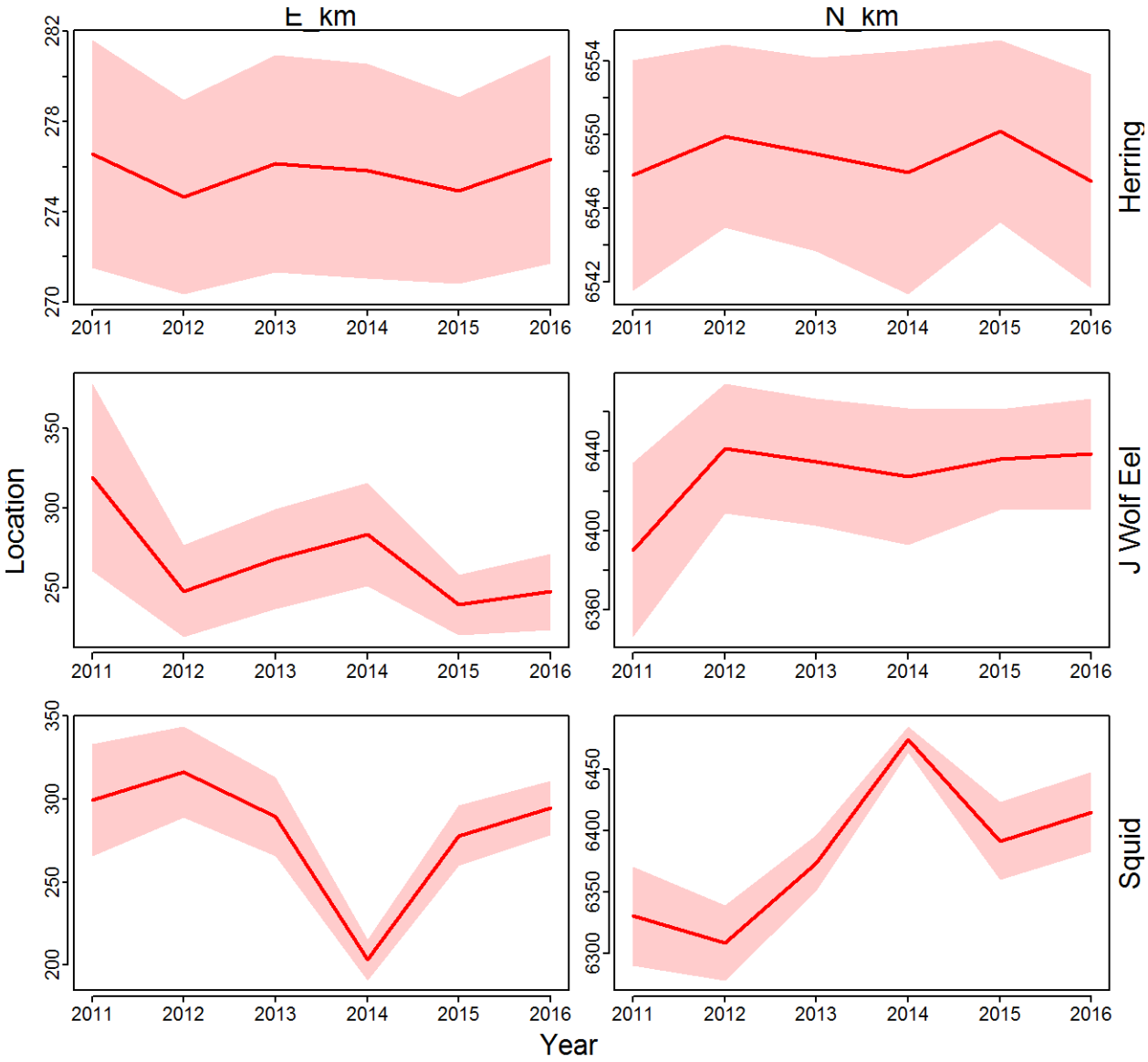

Figure 5. Center of gravity indicating temporal shifts in the mean east-to-west and north-to-south distribution plus/minus 1 standard error in UTM (km) for forage fish in the eastern Gulf of Alaska during summer, 2011-2016.

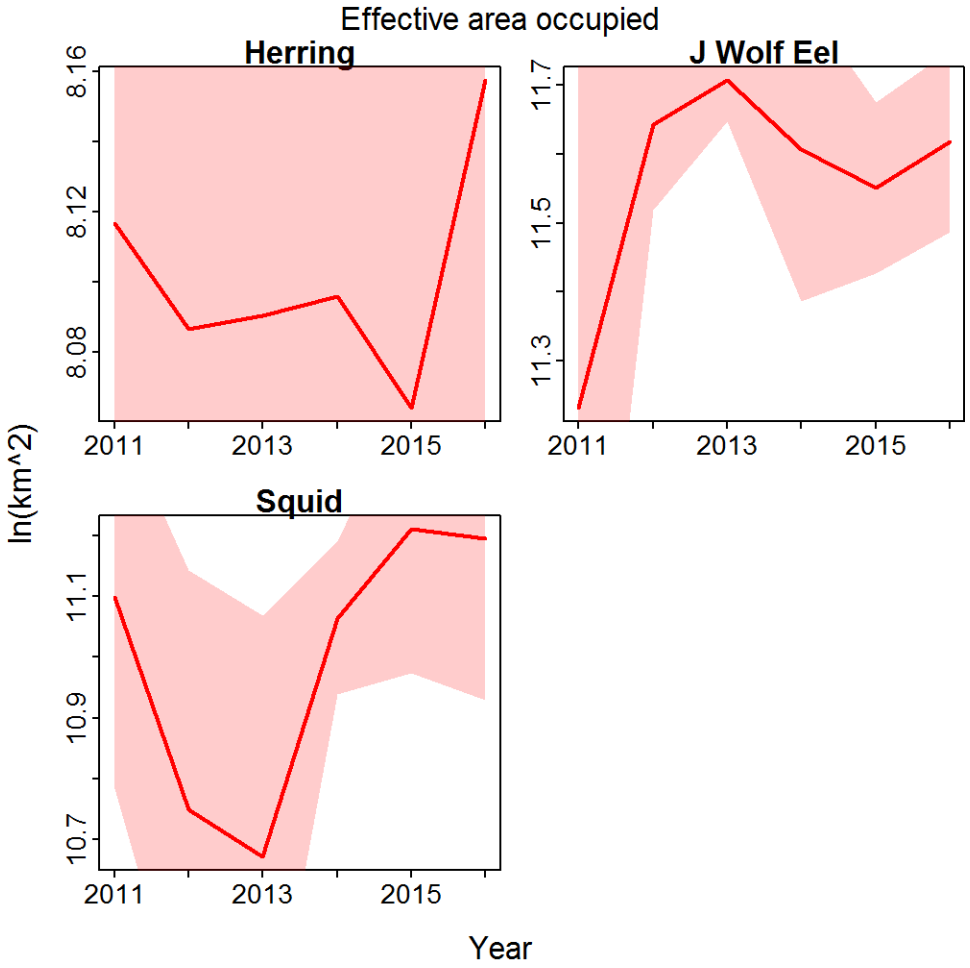

Figure 6. Effective area occupies (ln(km^2)) indicating range expansion/contraction plus/minus 1 standard error for juvenile Pacific salmon on the eastern Gulf of Alaska during summer, 2011-2016.

Table 1. Index of abundance (metric tonnes) plus/minus 1 standard error (SE) for forage fish in the eastern Gulf of Alaska during summer, 2011-2016.

Year	Pacific herring	Squid	Wolf eel
2011	9740 (13,147)	23 (20)	13 (8)
2012	614 (1211)	49 (16)	8 (4)
2013	2827(3449)	81 (22)	11 (4)
2014	2503 (2224)	529 (81)	9 (3)
2015	31 (49)	89 (30)	108 (25)
2016	751 (444)	164 (45)	28 (7)