Dear Editor and Reviewers,

We deeply appreciate you and two reviewers for reviewing our manuscript carefully. We would like to thank for all of the kind, useful and critical comments. We hope that our responses and revise MS will be acceptable.

The comments by the referee highlighted with “Q” with the number, and our answers to comments highlighted with “A”.

Response to the first reviewer, Prof. George Hunt

Nishizawa et al document the distribution and abundance of short-tailed shearwaters in the southeastern Bering Sea and the Chukchi Sea in summer and fall. They also document the size and abundance of euphausiids available to the shearwaters. They find that the shearwaters are most abundant in the Bering in summer, but more abundant in the Chukchi in fall. They also find that euphausiid sizes in the Chukchi Sea were greater in fall than in summer. They conclude that shearwaters remain in the Bering in summer because the krill there are larger, and then only move to the Chukchi when the krill there have increased in size. The paper is potentially an important contribution, but needs some substantial revision before publication.

[Q1] I liked this paper in that it began with a hypothesis and then set about testing it. That said, the test is a bit less robust than it might have been. In their comparisons, they are forced to compare summer in the Bering in year 1 with summer or fall in the Chukchi in year 2 (except in 2013, when they looked at the summer in both the Bering and the Chukchi). There is now considerable evidence that krill recruitment was depressed from 2001- 2005, that an increasing biomass of pollock further depressed krill abundance until about 2008, after which krill abundance increased until about 2009, then declined (see Ressler et al., 2012, 2014; Hunt et al., In Press Deep-Sea res. II). As a result, there may be aliasing of the krill biomass by other factors that are unique to the different years. Thus, in the models of explanatory variables (Table 3), it would be good to include year. In Table 4, there is a spatial component (Bering vs Chukchi) as well as SST, Chl a, and slope. How much of the effects of slope or temperature is because of location? I do not think that this is a problem in tables 5, 6 and 7. What happens with krill size in fall in the Bering Sea (Table 2 suggests no fall samples in the Bering)?

[A] We appreciate the critical and helpful comments. Yes. There are many studies showing that the composition of krill species and their biomass varied between warm and cold years (Coyle et al., 2008; Pinchuk and Coyle, 2008), and also varied across years during the cold period (2008–2010) in the southeastern Bering Sea (Bi et al., 2015). This interannual variation of species composition and biomass during the recent cold period can be partially attributed to the changes in water temperature and salinity and also the changes in other physical and biological factors (Bi et al., 2015). These other factors include ocean currents, stratification (Buchholz et al., 2010), predation from walleye Pollock (Hunt et al., 2011; Ressler et al., 2012). These large interannual variation of krill biomass can be one of reasons explaining larger krill size in September 2012 in the Chukchi Sea than that in July 2013. Unfortunately, we did not have enough data (2 years sample in the Chukchi Sea during summer or fall with no fall samples in the Bering Sea) to examine the interannual changes (2012 vs. 2013) in the size and abundance of krill so could not put the "Year" as fixed effect factor in the model explaining changes in krill size and biomass (this sentence was described in P6, L23-27). Thus, we would like to discuss the possibility that the interannual variation in the abundance of krill might explain the change of distribution of short-tailed shearwaters in the DISCUSSION.

It is interesting to examine whether effects of slope or temperature on shearwaters occurrence differ between sampling locations, but our objective is to investigate seasonal shifts in shearwater's distribution from Bering Sea to Chukchi Sea and factors affecting them. So I pooled each sampling locations within the region (Bering Sea and Chukchi Sea) for our statistical analysis.

I responded to your all comments as below.

[Q2] You suggest that the increase of shearwaters in fall in the Chukchi is related to an increase in large krill there. Could it be due to a decrease in krill in the Bering? Could you have detected that?

[A] Thanks for the comment. Unfortunately, we do not have data on the size and abundance of krill in the Bering Sea in September. So we did not know if krill availability decrease in the Bering Sea in September. According to the previous studies based on the data collected by the mooring-buoy furnished with continuous echo sounder, ship-based acoustics and net samplings in the Bering Sea shelf, the size and abundance of krill decreased seasonally as followings.

Previous study based on MOCNESS sampling showed that in the southeastern Bering shelf, the mature *T. raschii* was abundant during May–June, while the smaller immature was abundant during August–September (Coyle and Pinchuk, 2002). Krill eggs and nauplii collected using CalVET net (CalCOFI vertical egg tow) in the southeastern Bering Sea shelf were more abundant during May–June (56 m^{-3} in 1997, 133 m^{-3} in 1998 and 306 m^{-3} in1999) than during August–September (0.2 m^{-3} in 1997, 11 m^{-3} in 1998 and 3.5 m^{-3} in 1999) in all three sampling years (1997-1999), indicating that the most of the spawning of krill apparently occurs in May–June in the southeastern (Coyle and Pinchuk, 2002). The other study using MOCNESS tows showed also that high abundance of krill nauplii on the inner shelf of southeastern Bering Sea occurred in mid-May to June (Smith, 1991). Continuous echo data collected by the mooring system in the southeastern Bering Sea in 2006 showed that the densities of krill were high in July and decreased in August–September (Stafford et al., 2010) (described in P10, L8-24).

Hence, we believe that the abundance of krill in the surface layer likely decreased seasonally in the Bering Sea. Short-tailed shearwater feed on the prey only in the surface layer (<70m depth, Weimerskirch and Cherel, 1998). Thus, one of potential explanations on the seasonal shifts in shearwaters' distribution from the Bering Sea to Chukchi Sea might be the decreasing of the abundance of large sized krill that is availabile to the shearwater, especially mating surface swarm of krill in September in the southeastern Bering Sea. We also add the other potential reason, i.e., interannual change in krill abundance, in the DISCUSSION (described in P11, L12-P12, L7, see also reply Q7).

[Q3] You might be able to test whether there is a general pattern of decreasing numbers of shearwaters in the se Bering Sea by using the data available in the North Pacific Pelagic Seabird Database available at the USGS. Co-author Kuletz should be able to develop a nice set of figures from that.

[A] Thanks for the helpful suggestion. Sorry we did not use the data in the North Pacific Pelagic Seabird Database as it is not easily available and it does not include much data in the Arctic area. Instead, reported tracking- and boat-based studies indicate that the magnitude of interannual variation in the abundance of short-tailed shearwaters and reported seasonal pattern of distribution of the short-tailed shearwater seemed to be consistent among years. So, we believe that the seasonal shifts in the distributions of shearwaters might be a general pattern as explained as followings.

Tracked short-tailed shearwaters concentrated in the southeastern Bering Sea in July 2010 and 68% of them (13 of 19 birds) moved into the Chukchi Sea in September 2010 (Yamamoto et al., 2015). In contrast, only 38% of tracked shearwaters (9 of 24 birds) moved into the Chukchi Sea from the Bering Sea in September 2011 (Yamamoto et al., 2015).

Boat surveys in the Bering and Chukchi seas during early-July to early-August (the data were pooled in 2007‑2012) by Wong et al. (2014) showed that high densities of short-tailed shearwaters occurred in the Aleutian Islands, south Bering Sea and Bering Strait, but few birds were found in the Chukchi Sea. The other boat surveys in the northern Chukchi Sea during August-October, 2008-2010 by Gall et al. (2013) reported that short-tailed shearwaters were found there from mid-August to early-October, and the highest densities in September were common in all 3 years, though the densities of short-tailed shearwaters fluctuated by four orders of magnitude among years (the highest density was found in 2009 and lowest densities in 2008). These tracking- and boat-based studies indicate that the large interannual variation in the abundance of short-tailed shearwaters, but the trend of seasonal northward shift of the distribution of short-tailed shearwater was consistent among years. Thus, we are confident that short-tailed shearwaters stayed in the Bering Sea and Aleutian Islands in July and some of them were found in the Bering Strait and Chukchi Sea in September. But we also notes, thanks to the reviewer's comment, that there was large interannual variation in shearwater distribution. I added these explanations in the DISCUSSION part (described in P8, L30-P9, L14).

[Q4] Page 17723, line 1: Hunt 2011 would be better than Hunt 2002a

[A] Changed as you suggested.

[Q5] Page 17724, lines 16-19: the lack of observations in both places in the same year or in the same place, summer and fall complicates the analysis, as there may be considerable interannual differences in both the availability of krill, and in the numbers of shearwaters in the Bering.

[A] See replay Q2 and Q3. In the Chukchi Sea, information on seasonal and interannual variation in size and abundance of krill was very limited. We did krill sampling in Chukchi Sea in July and September. We found that krill size in July 2013 was much smaller than that in September 2012 and that the short-tailed shearwaters were more abundant in the area where large size of krill were abundant in September 2012 in the Chukchi Sea.

As in answer to Q2 and Q3, one of our explanation is that the seasonal shifts in short-tailed shearwaters distribution might be likely associated with decrease of the abundance of large size of krill especially mating swarm in the surface layer in September in the southeastern Bering Sea and increasing in large size of krill availability in September in the Chukchi Sea. Considering large interannual variation in abundance and distribution of krill and shearwaters found in the references, the other explanation is that short-tailed shearwaters were found in the Chukchi Sea in September 2012 and were not found there in July 2013, which might be related to that strong recruitments of krill (i.e., high krill abundance) occurred in 2012 and poor recruitments of krill (i.e., low krill abundance) occurred in 2013. This is now described in P11, L12-P12, L7 in the DISCUSSION section.

[Q6] Page 17724, lines 24 -26. These were apparently continuous counts of flying birds, rather than snapshot counts. This can complicate comparisons if in some places you encountered large flock of flying shearwaters, but in others most shearwaters were feeding or on the water.

[A] As pointed out, continuous counts of flying birds overestimate the density of flying birds (Tasker et al., 1984). Continuous count data will give information on relative density. We aimed to find environmental factors affecting the changes in seasonal distribution between Bering Sea and Chukchi Sea. So, relative density could meet our objective. In GLMM we used presence and absence of shearwaters as dependent variable.

[Q7] Page 17725, lines 15 – 18: 2012 was a cold year with late ice retreat, 2013 was a warm year with early ice retreat. The timing of the spring bloom and the recruitment of krill in these two years were likely VERY different.

[A] Thanks for these comments. We could not directly compare the abundance of krill between 2012 and 2013. We did not exclude the possibility that short-tailed shearwaters distributed in the Chukchi Sea in September 2012 but did not in July 2013 because of strong recruitments and high abundance of krill in 2012 compared to 2013 as following, though we did not have direct evidence. The first day when sea-ice concentrations were below 10% in the southern Chukchi Sea hotspot (68°03N, 168°50W) were 9 June in 2012 and 10 June in 2013. No sea-ice covered was found in the southeastern Bering Sea shelf (56^{o}40N, 163^{o}52W, location of Mooring 2) in both 2012 and 2013 (Figure S1). Thus this timing of sea-ice retreat did not differ largely between 2012 and 2013. SST in the southeastern Bering Sea shelf during April-October in 2012 and 2013 were 4.6±3.2^{o}C and 5.7±3.8^{o}C respectively, and SST in the southern Chukchi Sea during May-October in 2012 and 2013 were 2.3±2.6 ^{o}C and 3.6±2.7 ^{o}C respectively (Figure S2). Thus SST in 2012 were slightly lower than that in 2013 in both the southeastern Bering Sea shelf and southern Chukchi Sea.The surface Chla peaked on 14 May in 2012 and 10 May in 2013 in the southeastern Bering Sea shelf (56^{o}40N, 163^{o}52W) and on 20 June in 2012 and 12 June in 2013 in the southern Chukchi Sea (68^{o}03N, 168^{o}50W) (Figure S3). Thus the timing of spring bloom in 2013 was 4-8 days earlier than that in 2012. The growth and survival of krill are poor in the warm water years because of lack of food, i.e., ice-associated bloom, and high predation pressure due to the increase and range expansion of predator, i.e., walleye pollack (Stabeno et al., 2012). Therefore, recruitment of krill might be poor in 2013 because of warmer SST and earlier spring bloom compared to 2012.
I added these explanations in the DISCUSSION part (described in P11, L20-P12, L7).

[Q8] Page 17726, lines 5-8: Why not use length weight relationships for the species of krill in the

SE Bering? They are available in several publications (see Hunt et al., In Press). There are considerable interspecific differences in mass and in lipid content, and presumably both wet and dry weights per unit length.

[A] Thank you for the helpful comments. We used length weight relationships for the species of *T. raschii* (WW = 0.009 x $TL^{(3.02)}$, $R^2 = 0.95$, $p < 0.0001$, provided by Harvey et al. (2012) Deep Sea Res II) which predominate in the Bering Sea shelf to show biomass of krill collected in this study. I added the explanation in the MATERIALS and METHODS part (described in P5, L7-11). The biomass data was shown in the RESULT section (described in P7, L12-20).

[Q9] Page 17726, line 17-18: Is there a way to test this assumption? Are there not some small-scale differences in where krill are found? Anadyr water versus Bering Shelf Water in the northern Bering Sea?

[A] We used incorrect sentences, so removed it from the manuscript. We are very sorry for that.

[Q10] Page 17727, line 3 -4: I do not think that you can assume that slope is a good proxy for upwelling, but it may be. Can you check this?

[A] Thanks. Yes, we could not say that the slope is a good proxy for upwelling. Many previous studies showed that slope may be an important habitat of seabird (e.g., Yen et al. 2004 J of Marine Systems, Suryan et al. 2006 Deep Sea Res II, Zydelis et al. 2011 Proc R Soc Lond B). In this study, however, slope was not important factor explaining the distributions of short-tailed shearwater (Table 3). I removed the sentence “slope is a proxy for upwelling” from the manuscript.

[Q11] Page 17729, lines 8 – 10. Here you are contrasting not only the Bering and the Chukchi seas, but also, 2012 (cold and early bloom, likely strong krill recruitment) and 2013, (Warm and late bloom, likely very poor krill recruitment). In 2013, many of the krill may have been adults rather than first year recruits (Bering Sea *T. raschii* live 3-4 years).

[A] Thank you for the helpful comments. Please see the answer of [Q7].

[Q12] Page 17730, line 7: In view of no fall SE Bering Sea data, I think that “substantiate” is too strong. Perhaps “is in line with”?

[A] Changed from “substantiated” to “indicated” following your suggestion.

[Q13] Page 17730, lines 10 – 20: This is a very good point about seasons vs months. Even months may be misleading. Late August is "fall" in the SE Bering, as most birds leave the colonies in August, and migrant phalaropes and other species appear. Perhaps fall also begins in August in the Chukchi?

[A] I agreed with your opinion. The acoustic monitoring systems that was deployed in the southern Chukchi Sea showed that fin whale (*Balaenoptera physalus*) calls and the highest abundance of zooplankton were detected from August to October in both during 2012 and 2013 (Tsujii et al., 2016 ICES Journal of Marine Science). Mooring deployed in Hope valley of the southern Chukchi Sea from 16 July 2012 to 19 July 2014 showed that Chla concentration (45-53 m depth) increased sharply in May (2013 and 2014), when sea-ice still remained in this area, and high concentration continued until July, which is a spring bloom. In addition, relatively high Chla concentration (> 1 mg m^{-3}) were found in September-October 2012 and August-Octobor 2013, which is a fall bloom (Nishino et al., 2016 Biogeoscience).
Thus, "fall" probably begins in August in the Chukchi Sea. So I add the explanation as follows; We defined our survey periods of June–July as "summer" and August–September as "fall" respectively, considering that seasonality of phytoplankton bloom in the southern Chukchi Sea (i.e., spring bloom occur in May–July and fall bloom occur in August–October) (Nishino et al., 2016) (described in P6, L16-19).

[Q14] Page 17731, lines 3 – 7: You need to be a bit more explicit about the mechanisms for a temperature- driven impact on the availability of krill. Remember, T. raschii is apparently breeding until at least mid-August in the SE Bering Sea and shearwaters are foraging at breeding swarms then (Hunt et al., 1996). The main bloom in the Bering Sea is done in May or June. I am not certain that Yamamoto et al. (2015) put enough emphasis on the breeding chronology of T. raschii rather than on temperature.

[A] Thank you for the helpful comment. I modified the DISCUSSION part as follows. *T. inermis* (commonly found in middle and outer shelf domain) spawns in early spring (April-May) at the onset of the phytoplankton bloom and relies on lipid reserves to produce eggs. On the other hand, *T. raschii* (commnly found in the middle and inner shelf domains) reproduces later and for a more prolonged period through August-September with main spawning during May–June (Smith, 1991; Coyle and Pinchuk, 2002), apparently utilizing ambient food supplies. Some short-tailed shearwaters stay in the southeastern Bering shelf in August–September, and they feed on alternative prey, such as copepod, crab zoea and 0-age walleye Pollack or *T. raschii* that continued spawning until August-September (Hunt et al., 1996, 2002a) (described in P10, L25-P11,L1).

[Q15] Page 17731 lines 10 – 14: What they are eating may depend, in part, on where they were collected. Also, amphipods (*Thermisto libellula*) may be important only after a series of very cold years (Pinchuk et al., 2013).

[A] As suggested, the diet of short-tailed shearwaters are highly variable across areas, seasons, and years at small scale (Ogi et al., 1980, Schneider et al., 1986; Hunt et al., 1996, 2002a). However, major diet of short-tailed shearwater was krill. Thus, we were looking for the linkage between krill and the seasonal movements of migrating shearwaters. I add these explanations in DISCUSSION part as following;

Information on the diets of short-tailed shearwaters was not collected in this study. Previous studies have shown that krill comprised most of their diet in the northern North Pacific and Bering Sea (Table 7), although the diet of short-tailed shearwaters are highly variable across areas at a small scale, seasons, and years (e.g, Ogi et al., 1980; Hunt et al., 1996, 2002a). Other prey species included fish (19% in wet weight), squid (9%), copepods (1%) and crab larvae (2%) (Table 7). Within the krill prey items, *T. raschii* was the primary species (72–100%) for short-tailed shearwaters in the Bering Sea during the non-breeding periods (Schneider et al., 1986; Hunt et al., 1996, 2002a). Thus, in this study, we foucused on the linkage between distribution of krill and the seasonal movements of migrating shearwaters at a reginal scale (Bering Sea vs. Chukchi Sea) (described in P9, L15-24).

[Q16] Page 17731, line 27: size, and or abundance??

[A] Changed from “size of krill” to “abundance of larger size of krill” to become more clearly.

[Q17] Page 17732, line 5 – 8: May depend where one is sampling- remember Hunt et al. (1996) had lots of adult T. raschii at the surface in mid-August near the Pribilofs. See also the paper by Vleitstra et al.2005, where shearwaters were taking adult T raschii just north and east of Unimak Pass.

[A] See reply Q14.

[Q18] Page 17733, line 19: There are a number of papers specific to the SE Bering Sea summarizes in Coyle et al., 2011, Hunt et al. 2011, In Press).

[A] Thank you for the helpful comment. I modified DISCUSSION as following; The timing of sea-ice retreat can influence primary producers by modifying light availability which could in turn affect krill abundance (Stabeno et al., 2012). Late ice retreat (late March or later) leads to an early, ice-associated bloom in cold water, whereas no ice or early ice retreat before mid-March, leads to an open-water bloom in May or June in warm water. Krill abundance increased during the cold period when the extent of sea ice was large and decreased during the warm period (Coyle et al., 2008; Hunt et al., 2011; Ressler et al., 2012), though the mechanisms responsible for this are not clear. One possibility is bottom-up controls. A failure of food availability at a critical time (mismatch) may reduce the growth and survival of krill during the warm years. *T. raschii* relies on its stored lipids to overwinter (Falk-Petersen et al., 2000), and has been observed foraging on under-ice algae (ice-associated bloom) in the Bering Sea and feeding rates were enhanced when they were allowed to feed on large cells of ice related algae in the laboratory (Lessard et al., 2010). Or the warmer conditions with reduced ice coverage, early ice retreat, greater spring and summer solar radiation, and reduced wind mixing leading to smaller "cold pools" and warmer, stratified surface temperatures in summer are somehow unfavorable for krill. Because strong stratification in summer depresses post-bloom new production, therefore, the krill, lacking appropriate food resources, leave the water column when the surface layer warms (Coyle et al., 2008). Another possibility that high predation pressure due to the increase in predator (walleye pollock) abundance and the expansion of predator distribution (top-down control). However, a recent study by Ressler et al. (2014) suggested that the spatial distribution of krill did not show significant relationship with the abundance of walleye pollock (described in P12, L31-P13, L20).

Response to the second reviewer

[Q1] The phenomenal abundance of food in the Chukchi and Bering seas in the autumn provides for one of the greatest wildlife spectacles on Earth. Marine mammals and seabirds take advantage of a cascade of productivity begun months previously. The authors examine the spatial concordance between the abundance of seabirds (short-tailed shearwaters) and krill in the context of environmental features. They show that shearwater movement northwards coincides with an increase in krill size. The main drawback of the study is that it investigated relationships only at a single spatial scale. Relationships could be quite different at larger or smaller spatial scales, and it is too bad that some part of the study didn't look at a small spatial scale.

[A] We appreciate the helpful comments from the second reviewer. We calculated relative density (number of birds per km^2) of short-tailed shearwaters and used bird densities within a 50 km grid for the survey area. This grid size was determined because individual short-tailed shearwater stay within a region of 10 to 10^2 km for a few weeks in the southeastern Bering Sea and north Pacific (Baduini et al., 2006). Density of short-tailed shearwaters and 200 kHz back-scattering strength of acousitics, index of zooplankton abundance including krill, was positively correlated at a scale of 10 km in northern Japan Sea (Kurasawa et al., 2011). Our krill data is based on net sampling (12-140 km distance between nearest sampling locations), so we could not test it using our data. I add these explanations in the MATERIALS and METHODS (described in P4, L12-18).

Minor comments:

[Q2] Introduction, first paragraph. One of the best examples from seabirds for the effect of sea ice retreat is: Divoky GJ, Lukacs PM, Druckenmiller ML. Effects of recent decreases in arctic sea ice on an ice-associated marine bird. Progress in Oceanography. 2015 Aug 31;136:151-61.

[A] I added the example in the INTRODUCTION as follows; Recent sea-ice loss and the concurrent increases in SST in the western Beaufort Sea have reduced availability of Arctic Cod (*Boreogadus saida*), primary prey of the black guilmots (*Cepphus grylle mandtii*) breeding at Cooper Island in the western Beaufort Sea, which leads to their diet shifts to sculpin (Cottidae) with decrease in nesting growth and survival compared to that in the historical periods (1975–1984) (Divoky et al., 2015) (described in P2, L26-30).

[Q3] Introduction, second paragraph. It might be worth noting the first paper to document large-scale shearwater migration to nearby waters from a geolocator perspective: Shaffer SA, Tremblay Y, Weimerskirch H, Scott D, Thompson DR, Sagar PM, Moller H, Taylor GA, Foley DG, Block BA, Costa DP. Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. Proceedings of the National Academy of Sciences. 2006 Aug 22;103(34):12799-802.

[A] I added the example in the INTRODUCTION part (described in P3, L13-14).

[Q4] Introduction, L20. Seems strange to say "northern North Pacific" perhaps "extreme North Pacific".

[A] Thank you for the useful comment. The expression of “northern North Pacific” is widely used in the previous published papers (e.g., Kuma et al., 1998 Deep Sea Research I; Obayashi et al., 2001 Deep Sea Research I; Wong et al., 2002 Journal of Oceanography; Springer et al., 2003

PNAS; Yamamoto et al., 2015 Marine Biology), so I also used “northern North Pacific” following these papers.

[Q5] Introduction, last paragraph: add "the" before "net avoidance"; instead of "will...limit" perhaps "provide a rough estimate of krill abundance across several orders of magnitude."

[A] Revised following your suggestion.

[Q6] 2.1 L21. "an average speed" not "averaged speeds".

[A] Revised.

[Q7] 2.2 "collected" not "corrected".

[A] Revised.

[Q8] 2.3 first paragraph. Too bad you didn’t include abundances. Why not log-transform the data?

[A] Because densities of short-tailed shearwaters among 50-km grid cells were highly variable (Min.–Max.: 0–5,601.1 birds km^{-2}), and the sample size was relatively small (20 grid cells in fall 2012 and 52 in summer 2013), we first assessed the factors affecting the occurrence of short-tailed shearwaters. Then, we examined density of short-tailed shearwater and size of krill using simple Mann-Whitney U test approach.

[Q9] 4.1 L 16 "low densities" not "few" for parallelism with the previous part of the sentence.

[A] Revised.

[Q10] 4.1 L 20: “June” not “june”.

[A] Revised.