Biogeosciences Discuss., 12, C10327–C10336, 2016
www.biogeosciences-discuss.net/12/C10327/2016/

Biogeosciences Discussions
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Interactive comment on "Seasonal distribution of short-tailed shearwaters and their prey in the Bering and Chukchi Seas" *by* B. Nishizawa et al.

B. Nishizawa et al.

nishizawa@salmon.fish.hokudai.ac.jp

Received and published: 26 March 2016

Dear Editor and Reviewers,

We deeply appreciate you and two reviewers for very careful reviews of our manuscript. We would like to thank for all of the kind, useful and critical comment, and for extension of deadline. All of the comments are very helpful. We hope that our explanation and revise plan 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 [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

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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 useful comments provided by Prof. George Hunt. We totally agree with these comments. Previous studies focused mostly on the difference in krill species composition between warm and cold years (Coyle et al., 2008; Pinchuk and Coyle, 2008). In the recent study, during the cold period (2008–2010) krill species composition also changed substantially in the southeastern Bering Sea (Bi et al., 2015). The large interannual variation during the recent cold period can be partially explained by changes in water temperature and salinity. However, the potential factors likely include both physical and biological factors other than water temperature and salinity because they only explained about 50% of total variation (Bi et al., 2015). Physical processes such as ocean currents and stratification have the potential to affect krill survival, distribution and species composition interannually (Buchholz et al., 2010). Biological factors including predation from walleye pollock, a major predator of krill in the Bering Sea, can also affect krill abundances dramatically (Hunt et al., 2011, 2015). Thus, as the reviewer suggested, we would like to consider interannual variation in the krill biomass to include the year (2012 vs. 2013) in the habitat model analysis (Table 3). And also, we would like to consider the location (Lat, Lon) in the model to examine how much of the effects of slope or temperature is because of location. Although we do not have enough data (2 years sample in the Chukchi Sea during summer or fall with no fall samples in the Bering) to test whether the seasonal (summer vs. fall) or interannual changes (2012 vs. 2013) in size and abundance of krill would affect seasonal changes in shearwaters distribution (from Bering Sea to Chukchi Sea), we believe that our results can help understanding relationships between seabirds and their prey (krill) in the Bering and Chukchi seas at a reginal scale. Hence, we would like to add explanations on the interannual variation in the abundance of krill in the DISCUSSION as a one of possibility.

[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] Unfortunately we do not have any data on the size and abundance of krill in the Bering Sea during fall (September) to test whether krill biomass decrease in the Bering Sea in fall. According to the previous studies by the mooring with continuous echo sounder, ship-based acoustics and net samplings in the Bering Sea shelf, the size and density of krill decreased seasonally (Smith, 1991; Coyle and Pinchuk, 2002; Stafford et al., 2010). Studies based on MOCNESS sampling showed that in the southeastern Bering shelf, the mature T. raschii was abundant during spring (May–June) when the phytoplankton bloom occurs, while the immature was abundant during fall (August–September) (Smith, 1991; Coyle and Pinchuk, 2002). Continuous echo data collected by the mooring system in the southeastern Bering Sea showed that the densities of krill were high in mid-summer (July–August) and decreased in fall (September) (Stafford et al., 2010). Hence, we believe that most plausible explanation on the seasonal changes in shearwaters' distribution from the Bering Sea to Chukchi Sea might be related to seasonal changes in krill availability (both in size and density) at the reginal scale (Bering Shelf region vs. Chukchi Sea). We will improve these sentences in the DISCUSSION part more clearly.

[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

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Pelagic Seabird Database available at the USGS. Co-author Kuletz should be able to develop a nice set of figures from that. [A] We appreciate the useful suggestion. Tracked short-tailed shearwaters concentrate in the southeastern Bering Sea during summer (July) and they move to the Chukchi Sea during fall (September) (Carey et al. 2014, Yamamoto et al. 2015). Although our survey data on the distribution of shearwaters were very limited (only two cruises), we confirmed a similar pattern of seasonal movement from the Bering Sea to the Chukchi Sea. So, we believe that the seasonal changes in the distributions of shearwaters might be a general pattern. To make it more clearly, we would like to test whether there is a general pattern of decreasing numbers of shearwaters in the southeastern Bering Sea using the data available in the North Pacific Pelagic Seabird Database available at the USGS as the reviewer suggested.

[Q4] Page 17723, line 1: Hunt 2011 would be better than Hunt 2002a [A] Thank you for your careful reading. We will change the reference as the reviewer suggested.

[Q4] Page 17724, lines 12-13: expand? [A] We will add the detailed explanation on sampling bias due to net-avoidance by larger krill with progressed eye and sampling time (day time vs. night time) referred to the previous studies as below.

Sameoto, D., Cochrane, N., Herman, A., 1993. Convergence of acoustic, optical, and net-catch estimates of euphausiid abundance: use of artificial light to reduce net avoidance. Can. J. Fish. Aquat. Sci. 50, 334–346.

Wiebe, P.H., Lawson,G.L., Andone,C., et al., 2013. Improved agreement of net and acoustical methods for surveying euphausiids by mitigating avoidance using a net-based LED strobe light system. ICES J. Mar. Sci.70, 650–664.

Smith, S.L., 1991. Growth, development and distribution of the euphausiids Thysanoessa raschii (M. Sars) and Thysanoessa inermis (Krøyer) in the south-eastern Bering Sea. Polar Res. 10(1),461–478.

[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] As the reviewer pointed out, krill biomass (Hunt et al. 2015) and the abundance of short-tailed shearwater (Yamamoto et al. 2015) show interannual differences. Please see the answer of [Q1].

[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] Continuous counts of flying birds lead to overestimating the absolute density of flying birds (Tasker et al., 1984), but will give useful information on relative density of birds (Nishizawa et al. 2015). So, we can compare the density of birds between areas.

[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] We appreciate the useful comment. We will add the explanation about effects of interannual variation in the SST and timing of spring bloom on krill size and recruitment in the DISCUSSION part (see also the answer of [Q1]).

[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. As the reviewer pointed out, we need to use length-weight relationships for the species of krill in the southeastern Bering Sea. So, we use it for the species of T. raschii (WW = 0.009 x TL(3.02), R2 = 0.95, $p < 0.0001$, provided by Harvey et al. (2012) Deep Sea Res II) which predominate in the Bering Sea shelf.

[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] As the reviewer pointed out, we recognized that there is differences in the krill density between the sampling stations (Figure 2 and Results section 3.1, page 17728). We will add the detailed explanation on distribution of krill and relationships between krill density and environmental characteristics such as SST and Chla in the RESULT section "3.1 Distribution of short-tailed shearwaters and krill".

[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] Slope is potentially a good proxy for upwelling and known to be an important factor for seabird distributions (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). Although we could not test it directly, we can check it considering interaction term (SST x Slope) in the habitat models because upwelling is generally characterized by steeper slope and low surface temperature.

[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] We appreciate the useful comments. Please see the answer of [Q1] and [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] We agree with the comment, so will change the sentences as the reviewer suggested.

[Q13] 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] We appreciate the helpful comment. We will add more detailed explanation on the temperature impact on recruitment and growth of krill referring to new study Hunt et al., 2015.

[Q14] 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 the reviewer suggested, we recognize that there is differences in the diet composition of short-tailed shearwaters between sampling locations (i.e., shelf vs. basin). Even if we considered it, krill is one important food for shearwaters, especially in the southeastern Bering Sea during the non-breeding periods (Ogi et al. 1980, Hunt et al. 1996, Hunt et al. 2002, Table 7). So, we will add the detailed information about sampling locations in the Table 7 and the explanation in the manuscript.

[Q15] Page 17731, line 27: size, and or abundance?? [A] Our results suggest that seasonal distributions of short-tailed shearwaters may be associated with availability of large size of krill (> 8 mm provided by Vlietstra et al. 2005). We will modify the sentence more clearly as following; The northward movement of short-tailed shearwaters in late summer or fall might be associated with the seasonal increase in the abundance of large size of krill in the Chukchi Sea (Page 17731, Line 26-27).

[Q16] 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] As the reviewer suggested, we recognize that krill abundance varied between sampling location (at small spatial scales). However, at a reginal scale (Bering Sea and Chukchi Sea) and seasonal scale, changes in krill abundance and size apparently occur (e.g., Smith 1991, Coyle and Pinchuk, 2002,

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Stafford et al. 2010). Thus, we suggest that changes in availability of krill at these spatial and temporal scale may be associated with seasonal northward shift in the shearwater distribution.

[Q17] 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 your helpful suggestions. We will modify the last paragraph (Page 17733) including important effects on changes in krill biomass in the Bering and Chukchi seas; (1) bottom-up control by the availability of food (due to changes in SST, Chla and advection) (2) top-down control by walleye pollok predation referred to recent new studies (Hunt et al. 2011 ICES, Hunt et al. 2015 Deep Sea II, Bi et al. 2015 Deep Sea II, Ressler et al. 2012 Deep Sea II, Ressler et 2014 MEPS).

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 comment provided the second reviewer. We calculated relative density (number of birds per km2) of short-tailed shearwaters and used bird densities within a 50 km grid for the survey area; the grid size was based on short-tailed shearwater foraging area fidelity at a scale of 10 to 102 km in the southeastern Bering Sea and north Pacific (Baduini et al., 2006; Kurasawa et al., 2011). We would like to examine the relationships distribution between shearwaters and krill at larger (100 km) and smaller (10 km) spatial scales (Baduini et al., 2006; Kurasawa et al., 2011).

Unfortunately we do not have any data on the size and abundance of krill in the Bering Sea during fall (September) to test whether krill biomass decrease in the Bering Sea in fall. According to the previous studies by the mooring with continuous echo sounder, ship-based acoustics and net samplings in the Bering Sea shelf, the size and density of krill decreased seasonally (Smith, 1991; Coyle and Pinchuk, 2002; Stafford et al., 2010). Studies based on MOCNESS sampling showed that in the southeastern Bering shelf, the mature T. raschii was abundant during spring (May–June) when the phytoplankton bloom occurs, while the immature was abundant during fall (August–September) (Smith, 1991; Coyle and Pinchuk, 2002). Continuous echo data collected by the mooring system in the southeastern Bering Sea showed that the densities of krill were high in mid-summer (July–August) and decreased in fall (September) (Stafford et al., 2010). Hence, we believe that most plausible explanation on the seasonal changes in shearwaters' distribution from the Bering Sea to Chukchi Sea might be related to seasonal changes in krill availability (both in size and density) at the reginal scale (Bering Shelf region vs. Chukchi Sea).

[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 will add the reference.

[Q3] 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] As the reviewer suggested, I will add the reference.

[Q4] Second paragraph: l. 20. Seems strange to say "northern North Pacific" perhaps "extreme North Pacific". [A] We will change the words following suggestion.

[Q5] 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] We will change the words following suggestion.

[Q6] 2.1 L21. "an average speed" not "averaged speeds". [A] I will revise.

[Q7] 2.2 "collected" not "corrected". [A] Thank you for your careful reading. I will revise.

[Q8] 2.3 first paragraph. Too bad you didn't include abundances. Why not log-transform the data? [A] We appreciate the useful comment. We will use generalized linear models (GLM) where the log-transformed abundance of short-tailed shearwaters was the response variable, assuming a gaussian distribution.

[Q9] 4.1 L 16 "low densities" not "few" for parallelism with the previous part of the sentence. [A] I will revise following your suggestion.

[Q10] L 20: “June” not “june”. [A] Thank you for your careful reading. I will revise.

Interactive comment on Biogeosciences Discuss., 12, 17721, 2015.