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Interactive comment on "Turbulence and hypoxia contribute to dense zooplankton scattering layers in Patagonian Fjord System" *by* Iván Pérez-Santos et al.

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Interactive comment on "Turbulence and hypoxia contribute to dense zooplankton scattering layers in Patagonian Fjord System" by Iván Pérez-Santos et al. Anonymous Referee #2 Received and published: 18 December 2017

The manuscript aims at relating the vertical distribution and migration of zooplankton to physical structures and turbulence in Chilean fjord system. This is a timely and interesting focus. However, I find the manuscript in its present form preliminary and of local interest only. The difficulties are: The objectives of the study appear primarily of technical nature. The relevance and implications of studying the vertical distribution in

relation to fine scale properties and turbulent mixing needs to be highlighted in more detail. The introduction and the discussion basically lack scientific questions related to the physical-biological interactions and do not relate to an already large body of literature about detecting zooplankton with acoustic methods or the influence of physical (turbulence) or chemical (oxygen-minimum zones) properties on zooplankton distribution. The implied effects on reproduction, growth and life cycles in the introduction are not sufficient and appear redundant because the physical and biological processes occur on very different time cycles. Reference to previous work is largely restricted Chilean fjords. In addition, the material and methods are incomplete and inconsistent. Many details can be found below. It is unclear to me, why hydrographical data from 1995-2015 is presented, while zooplankton sampling is restricted to a few occasions. Data on zooplankton from net sampling in August 2014 is not presented although samples were apparently taken; instead physical data from 2016 is presented although not described in the Methods. Finally, the authors make very little use of their own data, particularly with regard to the identification of the primary groups responsible for the detected backscattering signals. The zooplankton depth resolved data should be presented and analysed. Data from 2013 suggests that copepods contribute very little to the signal, but the authors treat the backscatter data as equivalent to zooplankton throughout the manuscript. Tremendous differences in the abundance of zooplankton despite similar backscatter signal strength needs to be explained. In its present form, I cannot recommend considering the manuscript for publication and suggest that the authors revise it considerably.

Detailed comments:

Introduction âĂć Line 70: Palma (2008) is missing the reference list We added the reference of Palma (2008) to the reference list:

Palma S.: Zooplankton distribution and abundance in the austral Chilean channels and fjords. Progress in the oceanographic knowledge of Chilean inner waters, from Puerto Montt to Cape Horn. Comité Oceanográfico Nacional - Pontificia Universidad Católica

de Valparaíso, Valparaíso, Chile, pp. 107-113. Book on line at http://www.cona.cl/, 2008. âĂć Line 74: Landaeta et al. (2013) is missing in the reference list. When microzooplankton and fish larvae were studied, copepods (meso-and macrozooplankton) cannot dominate.

We added the reference of Landaeta et al., (2013) to the reference list:

Landaeta M., Martínez R., Bustos C. and Castro L.: Distribution of microplankton and fish larvae related to sharp clines in a Patagonian fjord. Revista de Biología Marina y Oceanografía, Vol. 48, N°2: 401-407, 2013.

As we mentioned in the text, microzooplankton and fish larvae were studied in Steffen fjord (-47.4° S). See new Introduction section.

âĂć Line 80 following: Rephrase the sentence. Why 'although'? What is meant by accurate results? Nets and acoustic methods provide principally different results with high taxonomic resolution in the first and high spatial resolution in the second. Thus, they are used to study different aspects and differ largely in their size resolution. We eliminated this sentence from text.

âĂć Line 88: Please specify: Norwegian Channel or Kattegat? We clarify sentence in the new Introduction section

âĂć Line 89: Buchholz et al. 1995, Zhou and Dorland 2004 are missing in the reference list.

We added the references to the reference list:

Buchholz F., Buchholz C., Reppin J., Fischer J. Diel vertical migrations of Meganyctiphanes norvegica in the Kattegat: Comparison of net catches and measurements with Acoustic Doppler Current Profilers. Helgolander Meeresunters, 49, 849-866, 1995. Zhou M., Dorland R. Aggregation and verticalmigration behavior of Euphausia superba. Deep-Sea Res. II 51, 2119–2137, 2004.

âĂć Line 89 following: The necessity and need for studying the vertical distribution or migration in relation to physical properties needs to be described better. They are themselves not a scientific question.

We explicitly state this now in the modified Introduction section.

âĂć Line 97: Please specify the implications for reproduction and growth. Yamasaki et al. 2002 is missing in reference list. We eliminated this paragraph from the text.

âĂć Line 101: The influence of the described processes (short-term) on biological life cycles (different time scales) needs to be explained.

The Introduction section was re-organized and this sentence was deleted.

âĂć Line 108: What is meant by 'survival strategies present in these organisms'?

We eliminated this sentence from the text. âĂć Line 111: It is unclear to me what the stage-specific migration patterns of Rhincalanus have to do with the effect of fine scale turbulence patterns. Acoustics cannot be used to resolve the stages of this species. âĂć We eliminated this paragraph from the text.

âĂć Line 115: The introduction lacks a review of the present knowledge about the effect on turbulent mixing and the oxygen conditions on the distribution of zooplankton. What are the scientific questions? What zooplankton is targeted at? Nets and acoustic profilers provide largely different type of data. âĂć We have addressed this in the modified Introduction section.

Material Methods âĂć Line 146: Specify the depths for nutrient samples. We eliminated the information on nutrients from the manuscripts.

âĂć Line 201: The description of the echo sounder needs to be checked. On line 188, it says SIMRAD CX 34 at 38 kHz, here it says EK-60 at 38 and 120 kHz. Please specify also how the echo intensity was combined. We added table 1 to clarify the sampling program and instruments used in each field campaign.

Table 1. Data set collected during different oceanographic campaigns in Puyuhuapi fjord and Jacaf channel. We added a new section to clarify the Acoustic methodology. See 3.2.1. Acoustic data analysis from echo-sounders

âĂć Line 210: Please explain the units (what is n and mi<square>. Zooplankton abundance is usually presented per unit volume, thus the full units should be presented (also of T)

The units of m2 n mi2 using to the nautical area scattering coefficient (NASC) is an acoustic unit used as an index of zooplankton abundance and it's not comparable to zooplankton abundance (Ind m-3) obtained with sampling nets. The unit of T is meter.

The NASC formula was eliminated from the text as was recommended by RC#1.

âĂć Line 217: What is 'Tx' in the formula?

Tx is the temperature at the transducer (°C) and is now included in the text.

âĂć Line 238: The sampling in 2013 covered only the upper 50 m but not the water column of 100 m scanned by the ADCP. Why? During May 2013 ADCP-1 was moored at 50 m depth to study the near-surface velocities of the fjord. This mooring was not orientated to the DVM of zooplankton research, but the backscatter data showed the first record of DVM in Puyuhuapi Fjord and then motivated the study of zooplankton using acoustic techniques.

âĂć Line 249: No information is presented on the analysis of the sampling. From the data presented in the study no differentiation into size classes was performed. Why?

We clarified in a new section (3.3 Zooplankton sampling).

Results: âĂć Line 254 following: In Fig 2, the top 100 m should be resolved because the size of the graphs make it very difficult to extract the information on T, S, and the other variables. The legend should be self-explanatory, but it is not. The T at the surface is 15 degrees, the x-axis stops at 14 degrees. The text and figures do not

always match: during Puy V hypoxic water occurred at a depth > 200m and not as implied by the text at >100 m. We eliminated figure 2 as was recommended by RC#1.

âĂć Line 263: The Mat Meth indicate that the sampling covered the period 1995-2015. Now data from 2016 are presented. This is confusing. Why was this data included? We clarified the information in the new section 3.1 Water column properties

âĂć Line 275: Sampling was conducted in layers of 10 m depth, but data on zooplankton distribution is averaged. Why? Information on size classes should be presented. In addition: was the abundance integrated as indicated in the figure legend? Then m-3 is wrong.

The data were presented as integrated to show the variation in abundance throughout time, and in particular, the increase in abundance during the first night hours, that we believe correspond to the start of the vertical migration upwards (e.g. at. 20.00h). The increase in zooplankton abundance resulted from their ingress from deeper layers during daytime hours. Integrated abundances may be expressed either as ind x m-2 or ind x m-3 (when divided by the depth of the water column sampled, 50 m at all sampling times in this case). We now explain this in the methods section In this new version of the manuscript we included the size classes of the zooplankton as requested by the reviewer and the vertical distribution (day vs. night) of siphonophores, chaetognaths and medusae (for example, as in the new figure 4). Euphausiids were not included in the new figure 3, because they were absent in most (all but one) samples probably because they were deeper and started to migrate upwards later at night than our last sampling hour at dusk.

-Fig. 4 c does not allow extracting quantitative information on siphonophores.

The data on siphonophores is shown now in the vertical distribution of the new figure 3 c-d (see previous answer)

-Figure 5: Apparently, zooplankton was analyzed in size categories; this needs to be

described in the methods.

This is now included in methods section.

A lot of information is lost by averaging/integration (this is not clear to me; it looks like averaging but integration is stated). I suggest to present the zooplankton data (size, taxa) as in Figure 5a despite a courser resolution. -Then, signal and zooplankton distribution can be compared.

The size data is now included and new subplots were added to show some examples of the vertical distribution. See new figure 4c-d.

Negative abundances in Fig c-e are odd. We eliminated this subplot from the figure.

-Zooplankton abundance in Jan 2014 (daytime) is several orders of magnitude lower than in 2013 (daytime), but signal strength appears similar or even higher. This needs explanation.

The zooplankton abundance of the larger size groups is lower in January 2014 than in May 2013 (3x or 4x) but not orders of magnitude. The largest differences are in copepods.

âĂć Line 303: The authors describe here that copepods and others together contribute to the signal in backscatter. This is not conclusive until the data is shown in high resolution as described above. In addition, a similar analysis needs to be done with the 2013 data, whit apparently strongly diverging results (copepods apparently do NOT contribute to the signal). We clarify the sentence in the new manuscript.

âĂć Line 308: To which depth do the Euphausids migrate to? Hypoxic water? The in-situ zooplankton sampling did not extend to the hypoxic water, which is why the results show the Euphausids migrating only in the first 100 meters of the water column.

âĂć Figure 6: The material and methods say that the signal of ADCP and Simrad were combined (38 and 120 kHz). Which signals were used for the along fjord transects?

We used 38 kHz in the along fjords transects. We clarified this information inside the figure and in the figure caption. We also reiterate this in the manuscript text.

âĂć Is the analysis comparable to the fixed stations? Line 318: ': : : demonstrated a uniform distribution of zooplankton'. This statement implies that the echo sounder provides a quantitative estimate of the groups studied, which is very likely not the case (see comments above). The authors should be more careful. He signal does not show any variation. We eliminated this sentence from the text.

âĂć Line 321: Why figure 6? We have clarified this.

âĂć Line 325: The NASC in the small figure included in Fig 6 is barely readable. How was the signal for fish and zooplankton obtained? The methods do not provide sufficient detail. There seem to be little differences at greater depth depending on the stations. We added new subplots to the new figure 5 (see above) that show the average values of NASC from zooplankton during daytime and night hours (Fig.5b and Fig. 5e). Also the average NASC of fish was also calculated and maximum NASC values were observed similar to the echogram, but NASC values were higher than NASC from zooplankton due to the difference in Sv magnitude. In this work the fish representation was only utilized to understand the prey-predator relationship, as we now mention in the Discussion section.

âĂć Line 342: this is interpretation of the results, and should not be presented here. Again, I advise to avoid the general term zooplankton because the back-scattering likely represent only a part of the zooplankton. This needs to be extracted from the ADCP and zooplankton sampling. We clarified the sentence in the new text. âĂć Line 347: The methods state that zooplankton was analysed in August 2014. The data is not presented. Again, avoid to assign zooplankton in general to the backscattering signal.

We clarified the sentence in the new text. In this new version of the manuscript we show the zooplankton data from August 2014 in Jacaf Channel (Figure 8). The zooplankton

data show increases in abundance during night hours (compared with daytime hours), the rising of zooplankton groups at night and most groups showed highest abundances at 100-150m during the daytime, which is deeper than in Puyuhuapi Fjord.

âĂć Figure 7: the legend says zooplankton and fish, the figure shows 38FL, 38 BN and fish. How was noise identified? We added a new section to clarify the Acoustic methodology. “3.2.1. Acoustic data analysis from echo-sounders”.

âĂć Line 359: Describing the signal is not a confirmation.

We clarified the sentence in the new text.

âĂć Line 362: The in-situ (nets?) data is not shown. How can Euphausiids attributed to the signal?

The new figure 8 showes this information.

âĂć Line 371: What is meant by ‘in-situ plankton sampling’? The echo-sound data? Zooplankton sampling with nets was conducted. The data is not shown. We clarified the sentence in the new text.

âĂć Line 373: The analysis needs explanation in the introduction and the methods. Why is a correlation between Sv and T to be expected?

We added a description of the statistical methods applied to compare the signal Sv to environmental data, such as zooplankton groups, dissipation rate of turbulent kinetic energy (ε) and also ε vs. zooplankton groups. The new information is now included in Section 3 Data and methodology section.

âĂć Fig 10 e and f: The methods do not describe how the measurements of energy dissipation with a resolution of 1mm where integrated to match the resolution of the backscatter analysis of 1m. We eliminated this figure from text as recommended by R1.

âĂć Fig 11: Why is this presented? Figure 11 was presented to evidence the intense

shear layers measured over the sill in Jacaf Channel. The direct measurements of shear allowed are linked to the high dissipation rate of turbulent kinetic found near the sill favoring vertical mixing and aggregation of plankton around the sill.

Discussion:

âĂć There is quite some literature on the relationship of zooplankton distribution in relation to oxygen minima and the relationships of zooplankton distribution and echo-sounder signals. These need to be explored.

Thank you for the comment, it helps to clarify and highlight some of the results obtained in the study. New literature is now mentioned in the manuscript.

âĂć What do the present results add to these studies?

As we now mention in the discussion section:

This study represents one of the first attempts to combine measurements of acoustics, stratified plankton sampling, microstructure profiles, and standard hydrographic profiles to investigate both the vertical distribution patterns of zooplankton and why these patterns exist in northwest Patagonian Fjords and other subantarctic latitudes. Three main findings resulted from this effort. First, DVM patterns of zooplankton became evident from all methodological approaches, at all study periods: May 2013, January 2014 and August 2014 (Fig. 3-8). Second, strong evidence arose showing zooplankton avoidance of hypoxic layers. And, third, a clear increment of zooplankton and fish aggregations around the Jacaf sill could be related to increased turbulence in this area.

âĂć The authors use their own data very little to explore the identity of the backscatter signal and to provide an analysis of general interest about the influence of physical factors and zooplankton beyond a local description. This needs to be conducted before any conclusions on implications of their relation to turbulence and implications for vertical flux can be made.

We have now included day and night profiles of zooplankton vertical distributions during

all field campaigns. In addition, we have included data on the major zooplankton groups present in the fjord (by species and size) and provide more information on the type of backscatter signal used to differentiate between major zooplankton groups and fishes. Regarding aspects of general interest, in the previous answer we mentions how the manuscript now better describes our results.

âĂć Line 508: How the authors come to the conclusion that copepods cause the backscattering signal in the deep, hypoxic layer is unclear to me.

We deleted this sentence

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