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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 #3 Received and published: 19 December 2017

Summary: The article analyses a dataset of ADCP, echosounder, CTD, turbulence and biological data in a fjord which is showing suboxic conditions in the deeper water column. The ADCP, echo sounding and biological data show a clear daily vertical migration pattern within the upper 100 m of the fjord. Turbulence measurements in the

main fjord and in the Jascaf channel show different regimes, with strongly increased levels of turbulence in the Jascaf fjord. The authors try to correlate oceanographic conditions with abundance of zooplankton and its daily vertical migration.

Comment:

âĂć While this is a very nice combined dataset of physical parameters and biology the processing and conclusions from this work have to be more elaborated before its ready for publication. One fundamental parameter used is the relative abundance of zooplankton derived from acoustic backscattering. To my understanding the authors have the data to calculate this correlation by using the data in Fig. 4 and 5. It is not clear what turbulence data is used in this article.

The turbulence data were used in this article to justify the abundance of zooplankton around Jacaf sill. We believe that turbulence generated by tidal flow interacting with the shallow sill produced intense tidal currents and is the principal mechanism contributing to mixing in the fjord. As a result, this enhanced the nutrient availability to the phytoplankton, generating excellent conditions for the zooplankton and thus leading to increased aggregation in this area. This situation was not observed in Puyuhuapi fjord, where turbulence was less intense.

âĂć While there are two device (SCAMP and VMP-250) the data suggest that only the VMP-250 is used (Fig. 10 and 11), that has to be clarified.

We removed the SCAMP information's and data from the text.

We included Table. 1 to better describe the characteristics of the different oceanographic field campaigns (see Table 1 below).

Table 1. Data set collected during different oceanographic campaigns in Puyuhuapi fjord and Jacaf channel.

âĂć Temperature microstructure is problematic in low as well as high turbulence regions, I wonder which device was used where.

We have now included the Table. 1 to better describe the characteristics of the different oceanographic campaigns and to detail which instruments were used during different campaigns. As we mentioned before the SCAMP data was removed from the text.

âĂć I would also like to see example temperature microstructure profiles with examples of fitted data, showing that the fit is reasonable. I can imagine that the temperature microstructure has problems in the deeper part of the Puyuhuapi Fjord (Fig. 10c) as well as in the extremely high dissipation region in the Jacaf channel (Fig. 10d).

We eliminated the old figure Fig. 10. As was mentioned by R3, SCAMP microstructure does not work well under strong tidal current conditions. Taking this into account, we decided to only include data from the VMP-250 (turbulence measured from velocity shears) from Puyuhuapi Fjord and Jacaf channel. See new figure 10.

âĂć Since tides are usually an important energy input for mixing, a section containing informations about tides is neccessary.

A new section was added that describes the tidal regime in Puyuhuapi Fjord and Jacaf Channel. See the new sections 3.4 and 4.5 below:

3.4. Tidal harmonic analysis The tidal constituents were computed using HOBO U20 water level loggers and the pressure sensor from ADCP-3 (Table 1-2, Fig. 1). A tidal harmonic analysis was applied to the sea level time series according to Pawlowicz et al., (2002), which considers the algorithms of Godin (1972, 1988) and Foreman (1977, 1978). We classified tides by the dominant period of the observed tide based on the form factor (F), defined by the ratio between the sum of the amplitudes of the two main diurnal constituents (larger lunar declinational, O1 and luni-solar declinational, K1) and the sum of the amplitudes of the two main semi-diurnal constituents (principal lunar, M2 and principal solar, S2), F = (O1+K1)/(M2+S2) (Bearman , 1989; where, F < 0.25 semi-diurnal, 0.25 < F< 1.5 Mixed semi-diurnal and F > 3.0 diurnal).

Table 2. Harmonic analysis implemented to water level time series in Puyuhuapi Fjord

and Jacaf Channel.

4.5 Tidal regime The harmonic analysis carried out with the sea level time series obtained in Puyuhuapi Fjord and Jacaf Channel, denoted the dominance (in terms of amplitude) of the semi-diurnal constituents (M2 and S2; Table 2). Diurnal constituents (O1 and K1) were also important, specifically at the Jacaf ADCP-3 station located close to the Jacaf sill region (Table 2 and Fig 1). The contribution of diurnal constituents added the mixed character to the tidal regimen in the study area. The spectral analysis implemented at all sea level stations showed maximum energy in the semi-diurnal band (Table 2), with the highest spectral energy (57.29 m2 cph-1) at Jacaf sill (Jacaf ADCP-3 station), which could be due to the extreme convergence of the channel at this location accelerating the tidal flows. âĂć Without a proper discussion I see no point in correlating all sorts of parameters against abundance of zooplankton (Fig. 9). The correlation does basically show that the zooplankton stays in the oxygenated water, which is already visible from the echo sounding transects. As this study is the first in Patagonian Fjords to establish a relationship between backscattering signals (Sv, proxy of zooplankton) with oceanographic variables, we believe it is important to show the temperature and salinity range where most of Sv values were observed. In the case of salinity, most of the Sv signal was located in oceanic water and not in estuarine water.

By correlating the different parameters we provide another way to show: that the zooplankton stay in oxygenated water.

âĂć For a person who is not familiar with DVM, it is from the article itself not clear, why zooplankton should migrate at all, a discussion about the reasons is needed. We include new information in the Discussion section to clarify the importance of DVM of zooplankton from Patagonian fjords and channels.

âĂć Vertical oxygen concentrations are not steadily decreasing towards deeper layers, Fig. 2f shows that towards the bottom oxygen increases again, are there reasons for that? We eliminated figure 2 from the text as was recommend by R2. The increase of DO values close to the bottom is due to deep ventilation processes that occur in this fjord. Pérez-Santos (2017), reported a deep ventilation event in the same area that helped to clarify and understand DO profiles in Puyuhuapi Fjord. The reference is: Pérez-Santos, I. Deep ventilation event during fall and winter of 2015 in Puyuhuapi fjord (44.6°S). Latin American Journal of Aquatic Research. Vol. 45(1). DOI: 10.3856/vol45-issue1-fulltext-25. âĂć A parameter which was not discussed at all is nitrate: There are nitrateclines, its hard to see if they are coinciding with the thermocline or halocline. Has nitrate a connection to zooplankton? Maby via phytoplanktion? We eliminated figure 2 from the text as was recommend by R1.

âĂć There is data from different seasons, is there a seasonality? The abundance (O(4000 ind m-3)) of May Fig. 4 seems to be much higher than in January (Fig. 5, O(200 ind m-3)). We included this information in the new Discussion section

âĂć In the introduction it was stated that the difference between the two echo sounding frequencies is used, the figures do anyhow show both frequencies separated (Fig. 7, 8), why is it so? We clarified this information in our response to R1 comments. These figures were changed. âĂć Phytoplankton was not really discussed through the article but is mentioned in the conceptual figure and briefly in the discussion. Are the any hints about the abundance and temporal evolution of it?

The phytoplankton studies in this region revealed seasonal behavior, represented by a productive season from August to April and a less productive season from May to July. The references are:

Daneri, G., Montero P., Lizárraga L., Torres R., Iriarte J.L., Jacob B., González H.E. and Tapia F.J.: Primary productivity and heterotrophic activity in an enclosed marine area of central Patagonia (Puyuhuapi channel; 44S, 73W). Biogeosciences Discuss 9, 5929–5968, 2012. Montero, P., Pérez-Santos I., Daneri G., Gutiérrez M., Igor G., Seguel R., Crawford D., Duncan P.: A winter dinoflagellate bloom drives high rates of

primary production in a Patagonian fjord ecosystem, Estuar. Coast. Shelf Sci., 199, 105-116, 2017a. Montero P, Daneri G., Tapia F., Iriarte JL. and Crawford D: Diatom blooms and primary production in a channel ecosystem of central Patagonia. Lat. Am. J. Aquat. Res., 45,(5), 999-1016, 2017b.

âĂć Fig. 12 also neglects that higher mixing might also deepen the mixed layer.

We changed figure 12. The new figure shows the position of the pycnocline deeper in Jacaf Channel than in Puyuhuapi Fjord. Also the nitrate and phosphate reference was eliminated. See new figure 12.

âĂć A comparison of vertical profiles of the VMP directly above the sill and in the fjord would be instructive.

A new figure was added to the manuscript to compare turbulence in Puyuhuapi Fjord and Jacaf Channel using the VMP-250 microstructure profiler.

âĂć Details: Fig. 2: A conceptual vertical profile at different position is needed. Two many profiles are on top of each other.

We eliminated figure 2 from the text as was recommend by R1. âĂć Fig. 3: Scale of salinity can be changed, the lower 15 gkg-1 are not used.

We changed figure 3 to the new figure 2.

âĂć Fig. 10 e+f: What does this correlation say?

We eliminated figure 10 from the text.

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