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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 #1 Received and published: 29 November 2017

Summary Perez-Santos et al. use a dataset comprised of hydroacoustics coupled with hydrographic measurements and zooplankton samplings to examine the effects of physical and chemical properties on zooplankton distributions in a Patagonian Fjord. Interdisciplinary data collected in this study is remarkable, covering biological, physical, and chemical properties. The authors achieved extensive coverage both temporally

and spatially by combining moored and ship-based surveys. However, this manuscript lacks clear objectives and significance of the study. As a result, I cannot comment on the significance of the study. The Introduction contains specific information about the Patagonian fjords, which are more relevant to the section titled "study area", without placing the study to the larger context. In addition, the paper does not do an adequate job analyzing the echosounder data. While the paper focuses on the zooplankton distribution, frequency of echosounder chosen (i.e., 38 kHz) is not relevant to examine zooplankton. Although the observations may be of interest, this manuscript is not yet ready for publication.

General comments Abstract does not contain the objectives of this study, instead heavily focused on the methods. There is fairly detailed description about the study site, which is more appropriate to place in the main text.

We have changed the wording of the abstract to contain the study objectives and have removed most of the verbiage about the methods. We have moved the description of the study site from the introduction to the study area section.

Introduction should include the objectives and significance of the study. Currently, there is not enough description on knowledge gap in this field based on previous studies and justification of the study site. Detailed description of the study site is more appropriate to place in the Methods.

We have restructured the introduction to include a more comprehensive literature review, explanation of the research gap, presentation of the specific goals of this work, tools used to accomplish these goals and an outline of the coming sections. We have moved the detailed description of the study site to the study area section.

I have major concerns on the analysis of echosounder data to extract zooplankton backscatter. In general, zooplankton species found in their net samples (e.g., copepods, euphausiids) cannot be detected at 38 kHz, because they are too small to be significant backscatterers compared to the wavelength of 38 kHz. How did the authors separate zooplankton from fish (Fig. 6)?

We added a new methodology section to the text (3.2.1 Echo-sounder data analysis) and some figures to address concerns of reviewer 1. Below is the section that was added to the manuscript:

3.2.1 Echo-sounder data analysis Post-processing of echo-sounder data was performed in Echoview (Myriax inc, Tasmania, https://www.echoview.com/), using the open access version ("FishZpkPeru38&120.evi") of Ballón et al., (2010)'s algorithm, which combines mean volume backscattering (MVBS) from 38 and 120 kHz, using both ΔMVBS (differences) and (summations) to discriminate and quantify the abundance of macrozooplankton. This algorithm separates raw data into three different virtual echograms: fish and two macrozooplankton groups (macrozooplankton or "fluid-like" and gelatinous or "blue noise" organisms). The fluid-like group follows a sphere model (Holliday & Pieper, 1995) considered appropriate to represent cylindrical and spherical shapes, including euphausiids and large copepods, which are dominant macrozooplankton groups off Peru and Chile (Ayon et al., 2008). The algorithm is considered to be useful for 38 and 120 kHz data from targets whose radius is $\geq$0.5 mm and has a dB difference of 2-19 dB (Ballón et al., 2010 and 2011). As implemented, the post-processing file FishZpkPeru38&120.evi is also designed to remove blind areas, near field, background noise and rainbow phenomenons. Given physical limitations imposed by sound absorption of selected frequencies (38 and 120 kHz) across the water column, an effective sampling of the water column up to 250 m was expected. Absorption is greater for 120 kHz, which exhibits the shortest range, but has a greater vertical resolution than 38 kHz. The 38 kHz frequency, on the other hand, exhibits a longer range, but limited resolution affecting small zooplankton (e.g. small copepods) detection. Nonetheless, this is the most commonly used frequency, which has proven to be efficient for studying macrozooplankton groups such as siphonophores, chaetognaths and euphausiids (Mair et al., 2005; Cade and Benoit-Bird, 2015; Ariza et al., 2016). Volume backscattering strength (Sv, dB re 1 m-1) values were integrated using a grid

of 20 m (depth) by 50 m (distance), and re-scaled into the customary index "nautical area scattering coefficient" (NASC, in units of m2 n mi2). Since NASC lies on the linear domain, it can be considered proportional to and suitable for indexing zooplankton abundance (Ballón et al., 2011). Ballón, M.: Acoustic study of macrozooplankton off Peru: biomass estimation, spatial patterns, impact of physical forcing and effect on forage fish distribution. These. Universite Montpellier II, 205 pp, 2010. Ballón, M., Bertrand A., Lebourges-Dhaussy A., Gutiérrez M., Ayón P., Grados, D., Gerlotto F.: Is there enough zooplankton to feed forage fish populations off Peru? An acoustic (positive) answer. Prog. Oceanogr., 91(4): 360-381, 2011.

When they have two frequencies (following Ballón et al. 2011), Sv data from 120 kHz is useful for up to _ 200 m depth due to the increase in background noise with range. However, the data analysis was conducted up to _ 450 m depth (Fig. 7). Only data within the analysis limit should be examined.

That is correct, the Ballón et al., 2010 algorithm shouldn't be used below 250 m (or even 200 m) if the purpose is quantitative. If used at depths below these the results become biased.

There is no discussion on the seasonal change in zooplankton distributions and compositions. Based on their seasonal coverage of the data sets, seasonal component should be considered in addition the difference in study sites.

We include a new discussion in the manuscript that incorporated the description of the seasonal behavior of zooplankton.

5.4 Other findings and considerations Results showed similar groups of macrozooplankton (>5 mm) in Puyuhuapi Fjord and Jacaf Channel: euphausiids, chaetognaths, medusae and siphonophores during summer (January 2014) and winter (winter 2014). However, euphausiids were not observed in fall 2013, which was an unexpected result which deserves further confirmation and analysis. In contrast, fall 2013 sampling presented the highest acoustic abundances within the time series (Fig. 3). The elevated accumulation of zooplankton species around the sill may impose a significant modification in the amount and quality of carbon exported to deeper waters in particular zones of the fjords. Future studies on carbon flux quantification in fjords should incorporate sill regions to test this hypothesis, in order to improve ocean pumping assessments in the context of climate change and variability.

The manuscript needs to be carefully reviewed for typos and grammatical errors. Comments from co-authors (lines 710-712) remained in the main text, which need to be removed. Section numbers are not in sequence in the Results, Discussion, and Conclusions.

We eliminated grammatical errors throughout the text and organized the sequence of Results, Discussion, and Conclusions.

Technical comments

Description of the data collection is complicated and hard to follow because there are many sensors deployed during different times of the year at different locations. Inclusion of a table summarizing the details (e.g., types of data collected, deployment locations/depth, period of data collection) would increase the readability of the manuscript.

We included Table. 1 to better describe the the different oceanographic field campaigns. The new table is given below:

The method lacks detailed description of the echosounders, such as ping rate, calibration information, and preprocessing of the data (e.g., bottom detection, near-field removal, background noise removal).

The deployed echo-sounder is a Kongsberg Simrad EK60 operating 2 split beam type transducers; the data produced is RAW format and contains power Sv and TS values in addition to angle coordinates of peak values at the depth of every sample. The calibration was made by using proper cupper spheres and procedure contained in the handbook of the echosounder.

We added new information to the Data and methodology section in the manuscripts in order to better describe the echo-sounder measurements and methods (Section 3.2.1):

Use of the word, echosounders, should be consistent throughout the text. The authors use “echo sounders”, “echo-sounders”, and “echosounders”, which need to be fixed.

We now use the word “echo-sounder” throughout the text.

Sv units, dB re 1 mËĘ-1, should be used throughout the text. The authors often use “dB” toward the end of the manuscript and figure legends and captions.

We changed Sv units in “dB” to “dB re 1 mËĘ-1” throughout the text.

Figures: Fig. 1: Color should be consistent between two colorbars. In the manuscript, red is SHALLOWER depth in the overview map, while red is DEEPER depth in zoomin figure, which are confusing. Some symbols overlap each other, which makes the readers difficult to understand the legends.

We eliminated the regional map from the figure to avoid confusion. We separated symbols. See new figure 1.

Fig. 2: Content of the figures on the top row overlaps with Fig. 3, and the patterns of the Jacaf Channel are very similar to those in the Puyuhuapi Fjord. Also, data points from previous studies are not discussed in the text. Thus, this figure could be removed from the manuscript.

We deleted figure 2 from the manuscript.

Fig. 3: Define “MSAAW”, “SAAW”, and “ESSW” in the figure caption. No definition of MSAAW and ESSW is stated in the text either. X-axis should be distance from the mouth, instead of latitude, because the fjord is positioned diagonally.

We added the complete name of water masses in subplot (c). We changed the x-axis distance from latitude to distance in km. See new figure 2.

Fig. 4: What does “AFIOBIOEX” mean? This term is not introduced in the text, but only appears in the figure captions (Fig. 5 as well). To improve the readability of the manuscript, AFIOBIOEX should be removed from the captions.

We eliminated AFIOBIOEX from the text. The new figure captions reads:

Figure 3. (a) Volume backscattering strength (Sv,) calculated from the ADCP-1 backscatter signal in Puyuhuapi Fjord, deployed at 50 m depth from the 8th to the 26th of May, 2013. (b) Zoom of the Sv data and the times of in-situ zooplankton sampling (black dots) carried out during May 25-26, 2013. (c) Vertical abundance of main zooplankton groups (>5 mm length) from the in-situ sampling at 18 h on May 25th and (d) 11 h on May 26th.

Fig. 5: The bars showing the standard deviation are not legible in (c)-(e). There is no x- and y-labels.

We eliminated this subplot from the figure and added new subplot (See new figure 4)

Fig. 6: X-axis of (a, c), and (d, f) is not consistent. All figures should be corrected for distance from the same reference point (e.g., distance from the mouth). What do the numbers in (b) and (e) mean? The upper bound of the hypoxia layer needs to be included, because it is not clear where the hypoxic layer is located.

We changed x-axis in subplots (d) and (f) to represent the same direction shown in (a) and (c). The numbers in (b) and (e) represent an index of zooplankton abundance (NASC: nautical area scattering coefficient) used in other manuscripts to estimate and quantify zooplankton biomass. We explain this now in the main body of the manuscript. Below are references for NASC:

Ballón, M., Bertrand A., Lebourges-Dhaussy A., Gutiérrez M., Ayón P., Grados, D., Gerlotto F. Is there enough zooplankton to feed forage fish populations off Peru? An acoustic (positive) answer. Prog. Oceanogr., 91(4): 360-381. 2011. Klevjer, T. A., Irigoien X., Røstad A., Fraile-Nuez E., Benítez-Barrios V. M. and Kaartvedt S. Large

scale patterns in vertical distribution and behaviour of mesopelagic scattering layers. Sci. Rep. 6, 19873; 2016. Sato, M., Horne J., Parker-Stetter S., Essington T., Keister J., Moriarty P., Li L., Newton J.: Impacts of moderate hypoxia on fish and zooplankton prey distributions in a coastal fjord. Mar. Ecol. Prog. Ser, Vol. 560: 57–72, 2016.

We included a new subplot in figure 6 (g) to better show the position of the hypoxic boundary layer and the hypoxic layer. The dissolved oxygen data was obtained between day and night-time acoustic sampling using continuous CTD profiles carried out approximately every 3 hours during January 23-24, 2014. We also added in subplots (a) and (d) the position of the hypoxic boundary layer. See new figure 5

Fig. 7: There is no need to plot the same data at two different frequencies. 38 kHz for fish and 120 kHz for zooplankton are commonly used in bioacoustic field.

We changed Fig 7 and Fig 8. See new figure 6 and 7.

Fig. 9: Which frequency is used for Sv values?

We used 38 kHz. We now make this clear throughout the main body of the manuscript.

Below is some examples of typos: Remove a period from the title. Line 69: change “has” to “have”. We changed ‘has’ to ‘have’ on line 69.

Line 98: add comma after “advection”. We eliminated this sentence from the Introduction

Line 104: add comma after “CTD profiles”.} We added comma after “CTD profiles”

Line 128-129: “northern mouth” cannot be identified in Fig. 1, because the subset of the figure blocks the portion of the fjord map.

The new Figure 1 shows the northern mouth.

Lines 143: Be consistent for the use of numbers (e.g., one vs. 1).

We changed the sentence.

Line 205: What does “CITA” mean? We eliminated CITA from the text.

Line 210: Ballón et al. (2011) is not in the References. We added the reference of Ballón et al., (2011) to the reference list.

Ballón, M., Bertrand A., Lebourges-Dhaussy A., Gutiérrez M., Ayón P., Grados, D., Gerlotto F.: Is there enough zooplankton to feed forage fish populations off Peru? An acoustic (positive) answer. Prog. Oceanogr., 91(4): 360-381. 2011.

Line 210: Unit of NASC is “mËĘ2 nmi-2”. The equation of NASC does not need to be presented, because this is a common knowledge. We eliminated the NASC equation from the text.

Lines 240-241: Remove the references, because these are commonly used techniques. We removed the references and also removed the reference of Castro et al., 2011 from the reference list.

Lines 243-247, 277-279: There is no need to include the study plan that did not happen. We eliminated this sentence from the text.

Line 266: What does “ESSW” mean? We clarify the mean of ESSW in the text as: Equatorial Subsurface Water (ESSW)

Line 274: Change “<” to “>”. We changed symbol in the text.

Lines 336-337: There is no time on the x-axis of Fig. 6. Time should be included on the x-axis, so that the readers can follow your interpretation. We included the information of the x-axis in the text.

Line 371: Change “+” to “and”. “DO” should be defined and used throughout the text, instead of using both DO and dissolved oxygen.

We defined Dissolved Oxygen (DO) in the Introduction section and changed dissolved oxygen to DO throughout the text.

Line 414: “Others” should be “other”.

We changed ‘Others’ to ‘other’.

Lines 425-428: This sentence is contradicting. Did you mean there is twilight vertical migration, or not? We clarify this in the new discussion section.

Line 469: Remove “(Fig. 10)”. This is duplication. We removed Fig. 10 from the text

Line 480: Cut “in” before “there might be”. We eliminated “in” from the text.

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2017-89/os-2017-89-AC1-supplement.pdf

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Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2017-89, 2017.

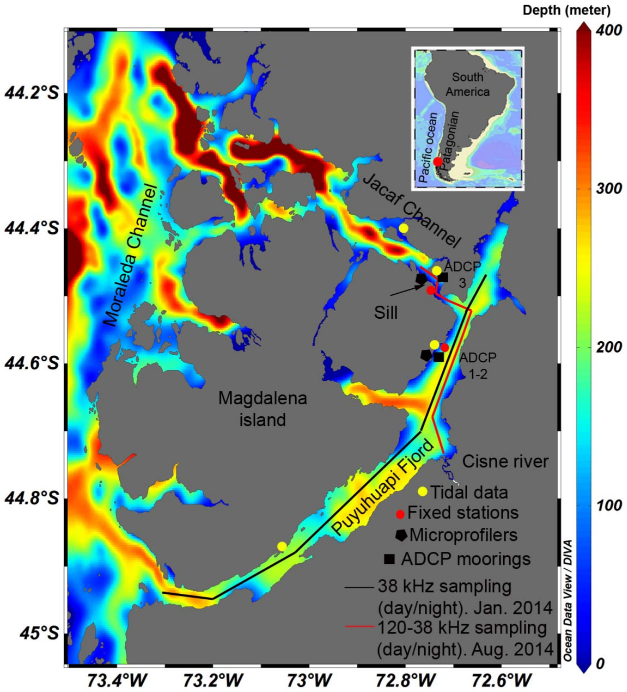
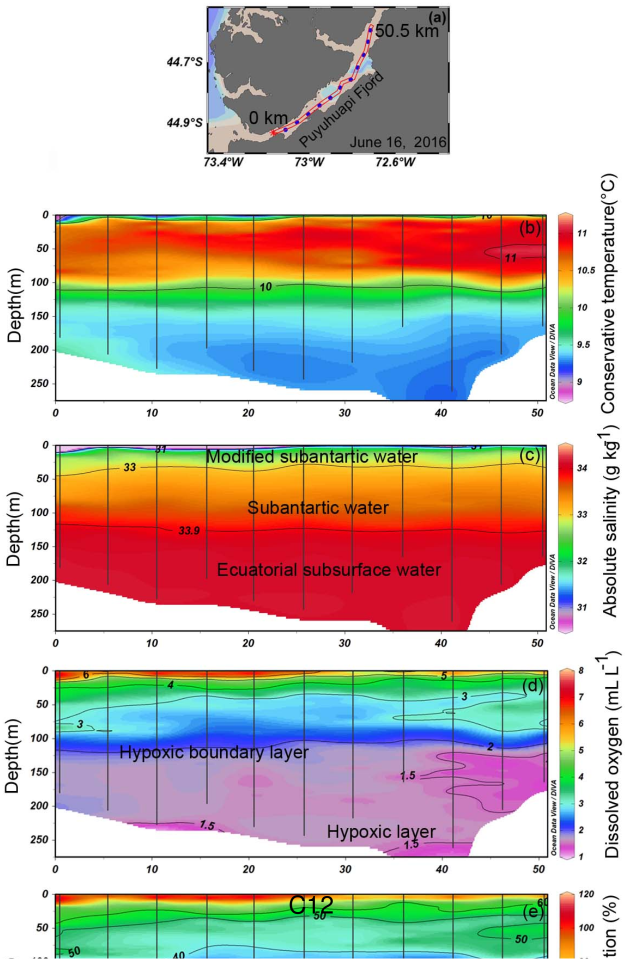


Fig. 1. Study area in relation to South America and the Pacific Ocean is the small panel in the top right. The main figure enlarges the study area (Puyuhuapi Fjord and Jacaf Channel) and indicates the instru



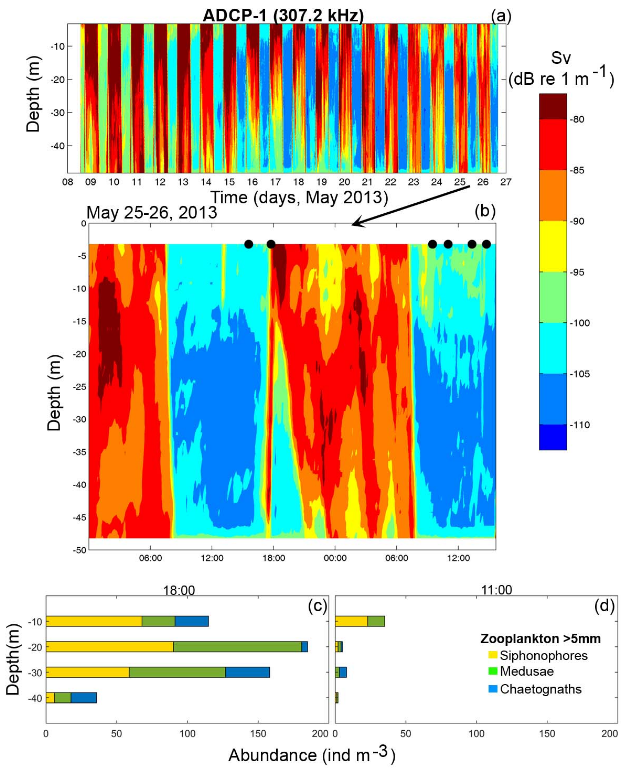


Fig. 3. (a) Volume backscattering strength (Sv,) calculated from the ADCP-1 backscatter signal in Puyuhuapi Fjord, deployed at 50 m depth from the 8th to the 26th of May, 2013. (b) Zoom of the Sv data and the

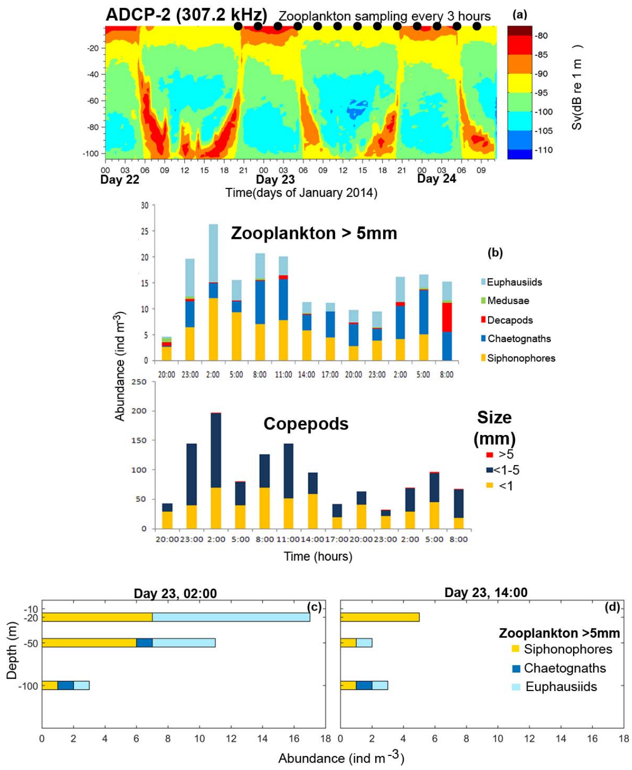


Fig. 4. (a) Volume backscattering strength (Sv) calculated from the ADCP-2 backscatter signal in Puyuhuapi Fjord from the 22nd to the 24th of January, 2014. The in-situ zooplankton sampling (in 3 h intervals)

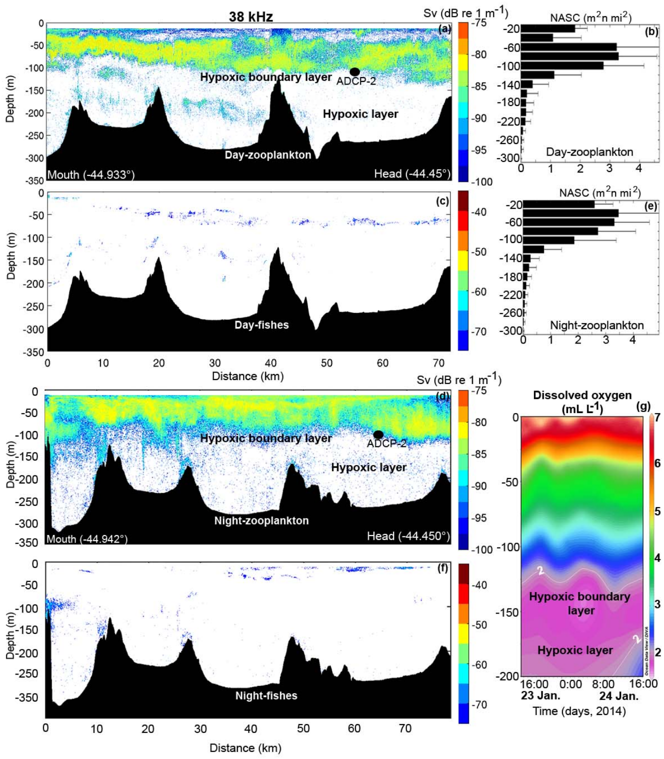


Fig. 5. (a) Volume backscattering strength (Sv) calculated from the ADCP-2 backscatter signal in Puyuhuapi Fjord from the 22nd to the 24th of January, 2014. The in-situ zooplankton sampling (in 3 h intervals)

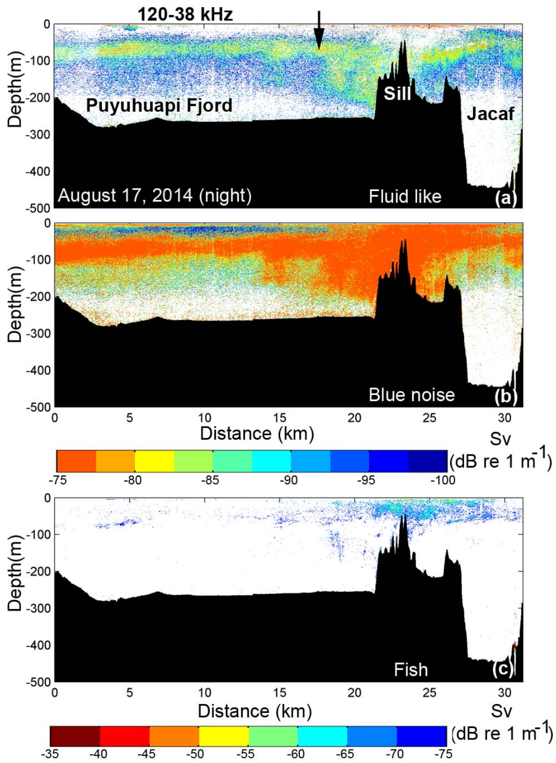


Fig. 6. (a) Scientific echo-sounder transects along Puyuhuapi Fjord (0-18 km) and Jacaf Channel (18-35 km)on August 17, 2014 using the combination of 38 and 120 kHz frequency. (a) Fluid like and (b) blue nois

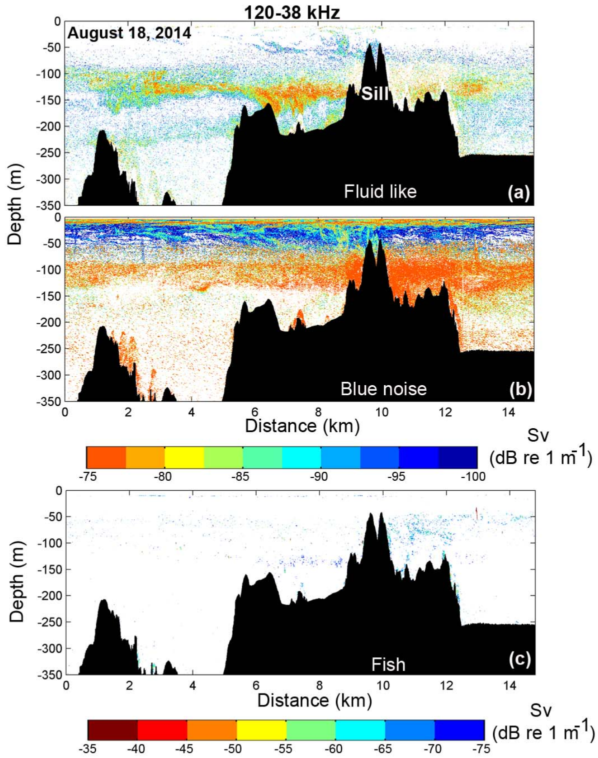


Fig. 7. Acoustic transect over Jacaf sill using the combination of 38 and 120 kHz frequency on August 18, 2014. (a)Fluid-like echogram, (b) blue noise echogram for zooplankton and (c) the fish echogram. Distr

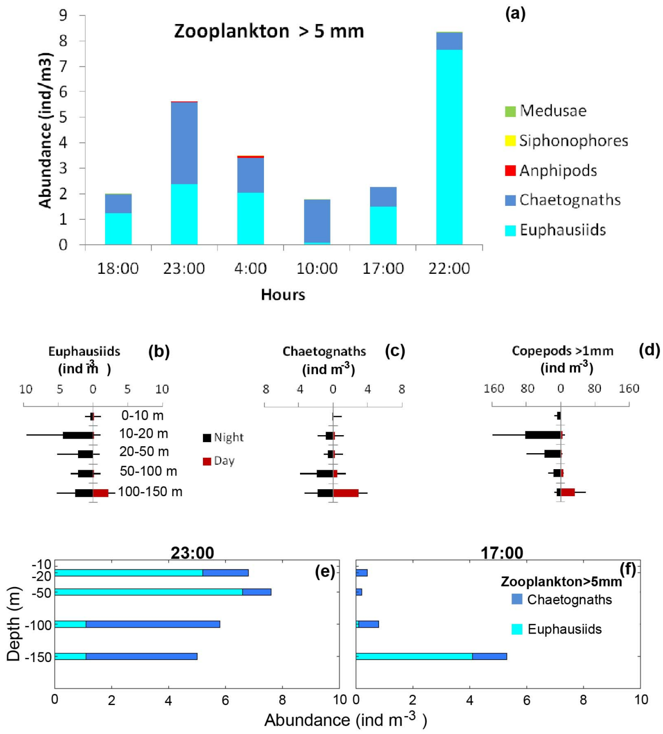


Fig. 8. (a) Depth integrated abundance of zooplankton groups from surface to 150 m depth for various sampling hours (b) euphausiids contined in depth strata (mean and standard deviation) during daytime (red)

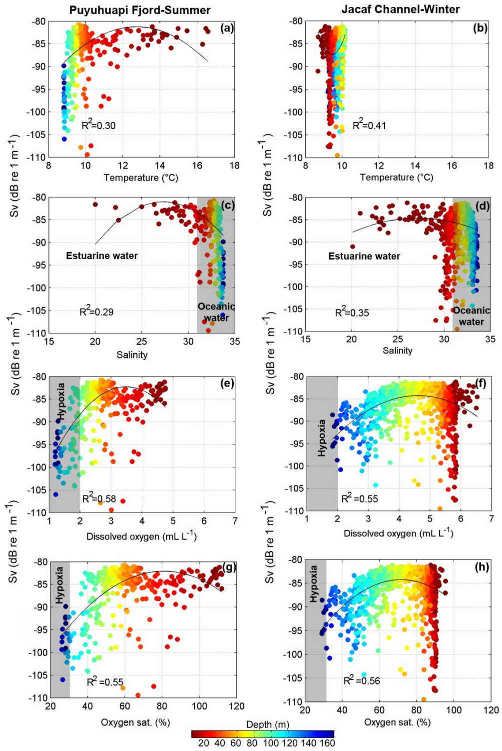


Fig. 9. Relationships between the relative abundance of zooplankton (expressed in Sv values) using 38 kHz frequency echo-sounder measurements (y-axis) and temperature in (a) Puyhuhuapi Fjord and (b) Jacaf Ch

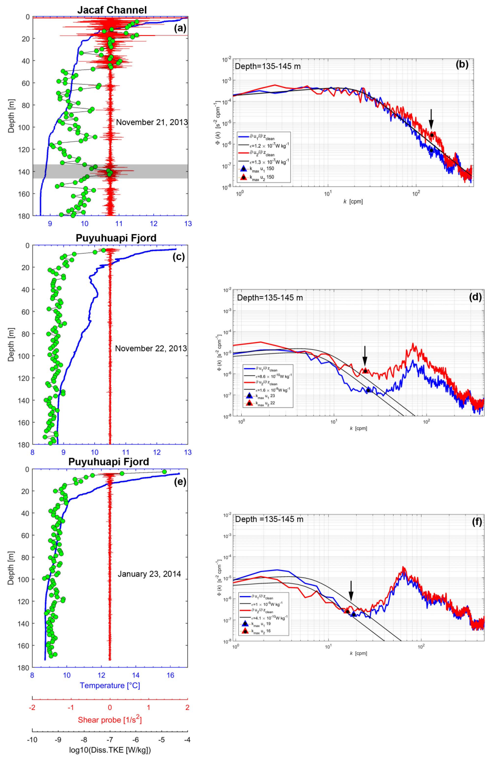


Fig. 10. Profiles of water temperature (blue line), vertical shear (red line) and dissipation rate of turbulent kinetic energy (black line with green dots) obtained with the VMP-250 microprofiler at the depth

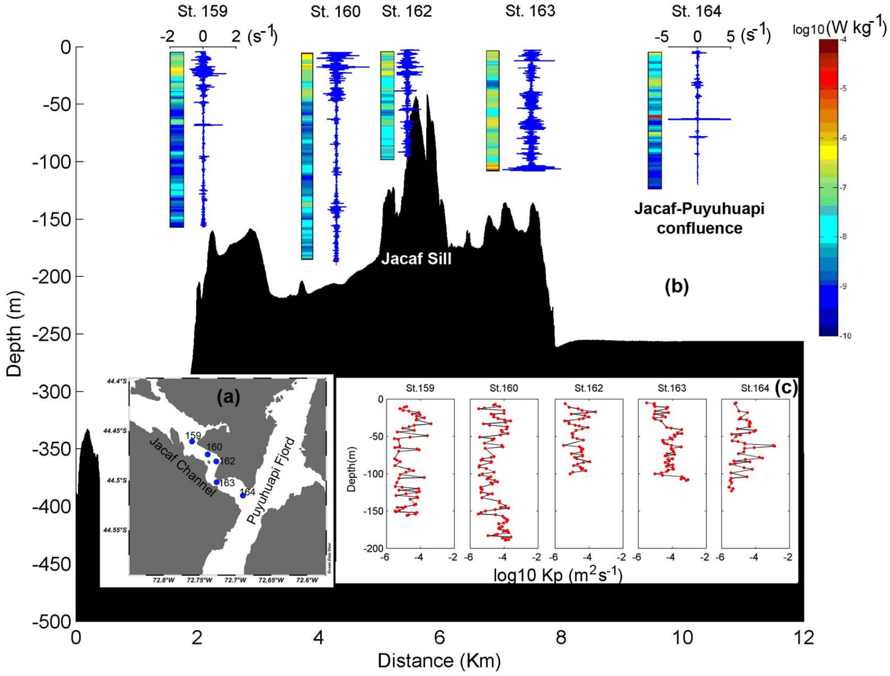


Fig. 11. (a) Microstructure profile locations along Jacaf Channel and sill using VMP-250 in November 2013. (b) The color bar showed the dissipation rate of turbulent kinetic energy (ε) and the blue lines depi

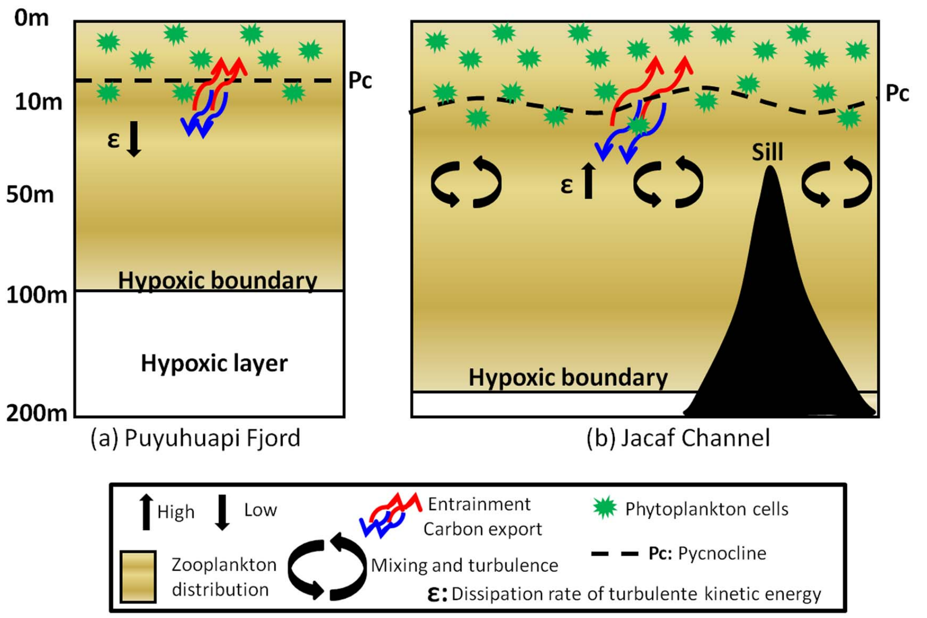


Fig. 12. Conceptual model to show the oceanographic processes that contribute to the distribution and aggregation of zooplankton in (a) Puyuhuapi Fjord and (b) Jacaf Channel.

Table 1. Data set collected during oceanographic campaigns in Puyuhuapi Fjord and Jacaf Channel.

Location	Date	Season	Data measured	Instruments
Puyuhuapi Fjord	May 8-27, 2013	Fall	-Acoustic data 300 kHz -Zooplankton	-ADCP-1 RDI -WP2 net
	January 22-25, 2014	Summer	-Acoustic data 300 kHz -Acoustic data 38 kHz -Zooplankton -Turbulence -Hydrography	-ADCP-2 RDI -SIMRAD EK60 -Tucker Trawl net -VMP-250 -YSI 6600
	August 17-19, 2014	Winter	-Acoustic data 38 and 120 kHz -Zooplankton	-SIMRAD EK60 -Tucker Trawl net
	February-June 2016	Summer-Fall	-Tidal data (south)	-HOBO U20
	February-November 2016	Summer-Spring	-Tidal data (north)	-HOBO U20
	June 16, 2016	Fall	-Hydrography	-CTD SBE-25
Jacaf Channel	April-November 2012	Fall-Spring	-Tidal data	-HOBO U20
	November 21, 2013	Spring	-Turbulence	-VMP-250
	August 2014-May 2015	Winter-Spring – Summer-Fall	-Tidal data	-ADCP-3
	August 17-19, 2014	Winter	-Acoustic data 38 and 120 kHz -Zooplankton	-SIMRAD EK-60 -Tucker Trawl net

Fig. 13. Table 1. Data set collected during oceanographic campaigns in Puyuhuapi Fjord and Jacaf Channel.

Table 2. Harmonic analysis implemented to water ~~sea~~ level time series in Puyuhuapi Fjord and Jacaf Channel.

Sea level time series	Date (mm-yyyy)	Energy from semi-diurnal band (m^2 cph^{-1})	Amplitude of principal constituents (cm)				F	Tidal regime
			M_2	S_2	O_1	K_1		
Jacaf-HOBO	04-09/ 2012	45.10	83.45	28.32	14.46	22.33	0.32	Mixed semi-diurnal
Jacaf-ADCP	08/2014-05/2015	57.29	60.67	61.01	57.78	42.48	0.82	Mixed semi-diurnal
Puyuhuapi-HOBO south	02-06/2016	44.45	81.97	31.51	13.37	18.36	0.27	Mixed semi-diurnal
Puyuhuapi-HOBO north	02-11/2016	49.17	89.15	31.07	11.03	17.75	0.23	Semi-diurnal

Fig. 14. Table 2. Harmonic analysis implemented to water level time series in Puyuhuapi Fjord and Jacaf Channel.