From polar night to midnight sun: diel vertical migration, metabolism and biogeochemical role of zooplankton in a high Arctic fjord (Kongsfjorden, Svalbard)

G Darnis[1*], L Hobbs[2], M Geoffroy[3], JC Grenvald[4], P Renaud[1], J Berge[5], F Cottier[3], S Kristiansen[5], T Gabrielsen[2], etc..

[1] Akvaplan-niva. Fram Centre for Climate and the Environment, N-9296 Tromsø, Norway.
[2] Scottish Association for Marine Science, Oban, United Kingdom, PA37 1QA.
[3] Université Laval, Pavillon Alexandre-Vachon, 1045, avenue de la Médecine, Québec (QC) G1V 0A6, Canada.
[4] University Centre in Svalbard, Pb 156, N-9171 Longyearbyen, Norway.
[5] Faculty of Biosciences, Fisheries and Economics, UiT The Arctic University of Norway, N-9037 Tromsø, Norway.

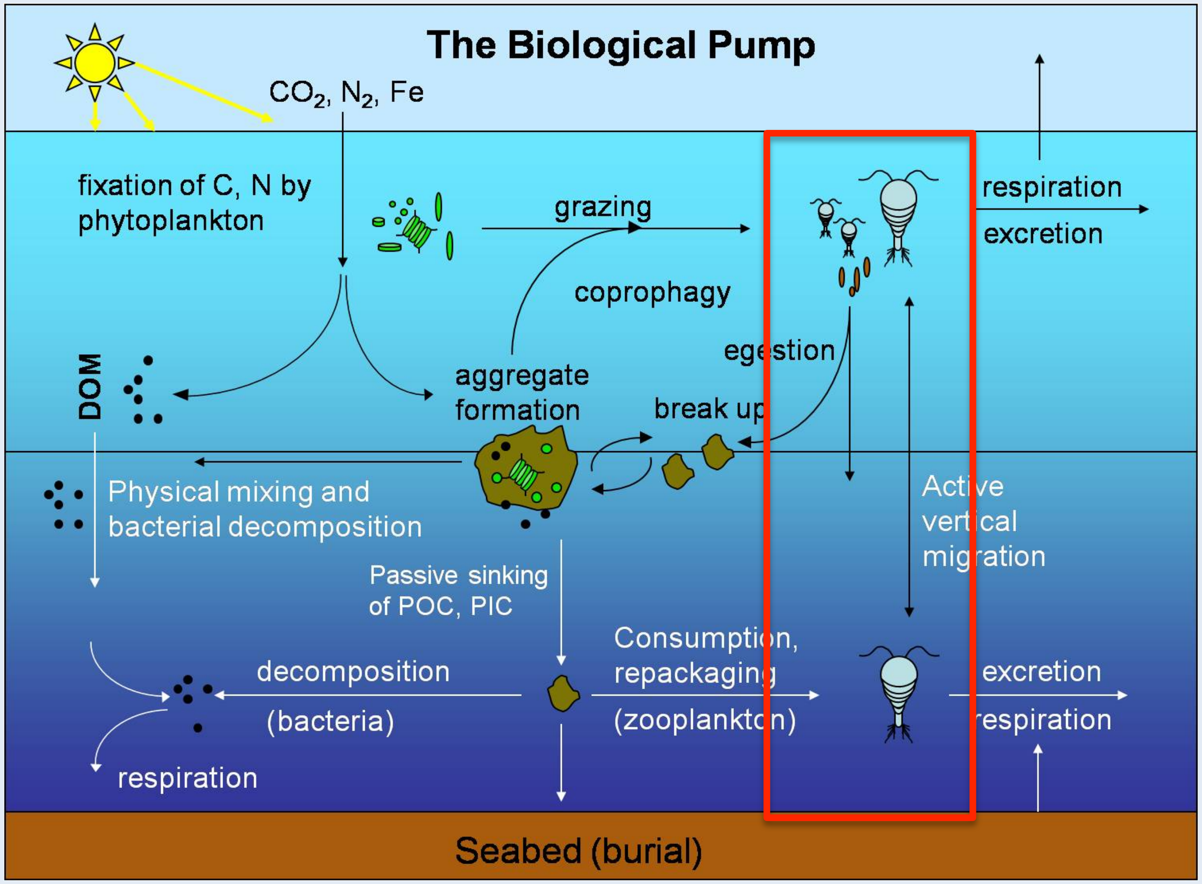
[*] Corresponding author: Gerald.Darnis@akvaplan.niva .no

Running title: Zooplankton migration and biogeochemical fluxes

Keywords: Zooplankton, Diel vertical migration, Carbon flux, Biological pump, Polar night, Arctic, Kongsfjorden

Role of DVM in biological pump

Export to ocean depths of carbon photosynthetically fixed in the photic zone.



(Ducklow et al. 2001, Oceanography)

Active respiratory carbon flux due to zooplankton DVM

Region	Depth (m)	Migrant biomass (mg C m^{-2})	Resp. flux (mg C m^{-2} d^{-1})	% of POC flux	Refs
Sargasso Sea	150	29	1.9	**3**	1
Eastern Equator	150	154.8 ± 32.4	7.3 ± 1.4	**15-20**	2
Bermuda	150	192 (84-540)	14.5 (6.2-40.8)	**30**	3
Canary	200	204.4 (108-341.5)	0.8 (0.5-1.4)	**1.1-2.7**	4
	200	124.8-247.8	1.9-4.3	**22-28**	5
	200	580-1280	1.8-8.3	**15-53**	6
ALOHA	150	157.9	3.7	**18**	7
Western Equator	160	367 (144-447)	22.7 (7.3-19.1)	**13-35**	8

[1]Longhurst et al.(1989); [2]Zhang & Dam (1997); [3]Dam et al. (1995); [4]Putzeys et al. (2011); [5]Hernández-Léon et al. (2001); [6]Yebra et al (2005); Steinberg et al. (2008); [8]Hidaka et al. (2001)

Quantify active respiratory carbon flux due to DVM in an high-Arctic marine ecosystem

Active nitrogen flux due to zooplankton DVM

Region	Depth (m)	Migrant biomass (mg N m^{-2})	Excr. flux (mg N m^{-2} d^{-1})	% of PON flux	Refs
Sargasso Sea	150	9	0.7	**8**	1
Central Pacific	300	9	3.6	**9**	2
Sargasso Sea	200	16 (0-92)	0.6 (0-7.7)	**13**	3
ALOHA	150	32	0.6 (0.2-1.6)	**7-35**	4
Bermuda	150	20-133	1.9 (0.8-5.3)	**17-82**	5
Equat. Pacific	200	8	3.6	**45**	6

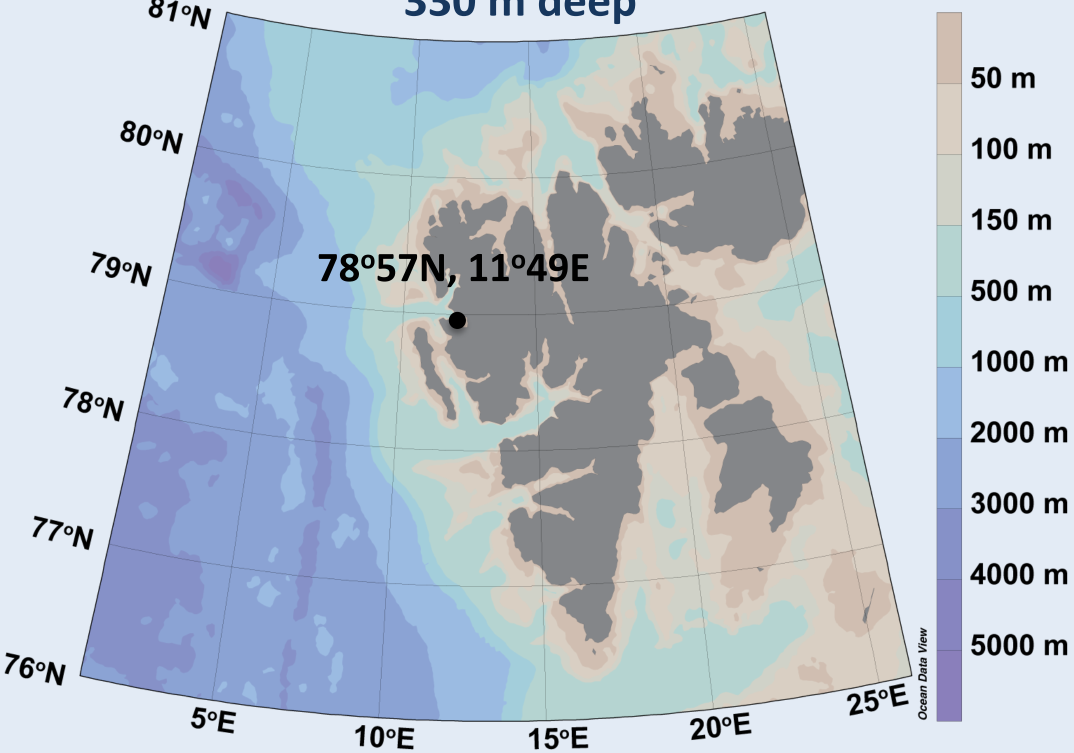
[1]Longhurst et al (1989); [2]Rodier & Le Borgne (1997); [3]Steinberg et al (2002); [4]Al Mutairi & Landry (2001); [5]Dam et al. (1995); [6]Le Borgne and Rodier (1997)

Quantify active nitrogen flux due to DVM in an high-Arctic marine ecosystem

CircA: Circadian rhythms of Arctic zooplankton from polar twilight to Polar Night - patterns, processes and ecosystem implications

Station KB3 in Kongsfjorden

330 m deep



- 16-20 January 2014
- 12-28 May 2014
- 23-26 September 2014

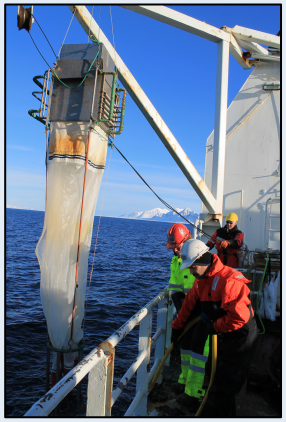
«*Helmer-Hanssen*»

Zooplankton sampling and analyses

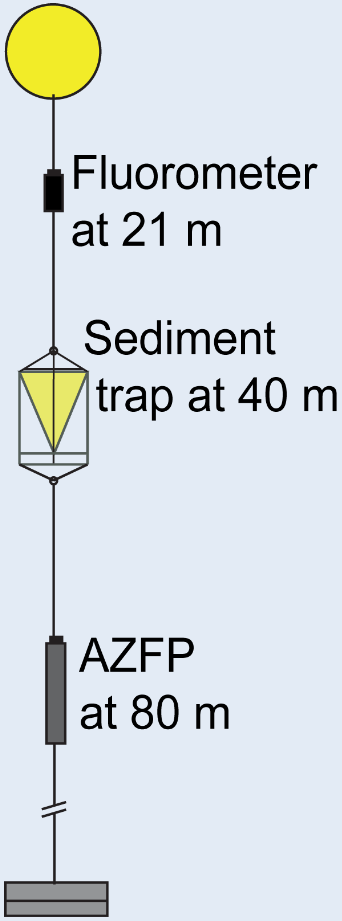
- Net sampling around **midnight** and **midday**
- MIK trawl in the 0-30 m layer for macrozooplankton
- Multinet profiles for mesozooplankton distribution
- Taxonomic analysis and size measurement of formalin-fixed zooplankton samples
- Measurement of macro- and meso-zooplankton respiration using a micro-optode system
- Dry mass of incubated zooplankton
- AZFP (125, 200, 455, 769 kHz) at 80 m from 17 Jan to 9 September
- Sediment trap at 40 m depth
- Fluorometer at 20 m depth

MIK net 1500 µm

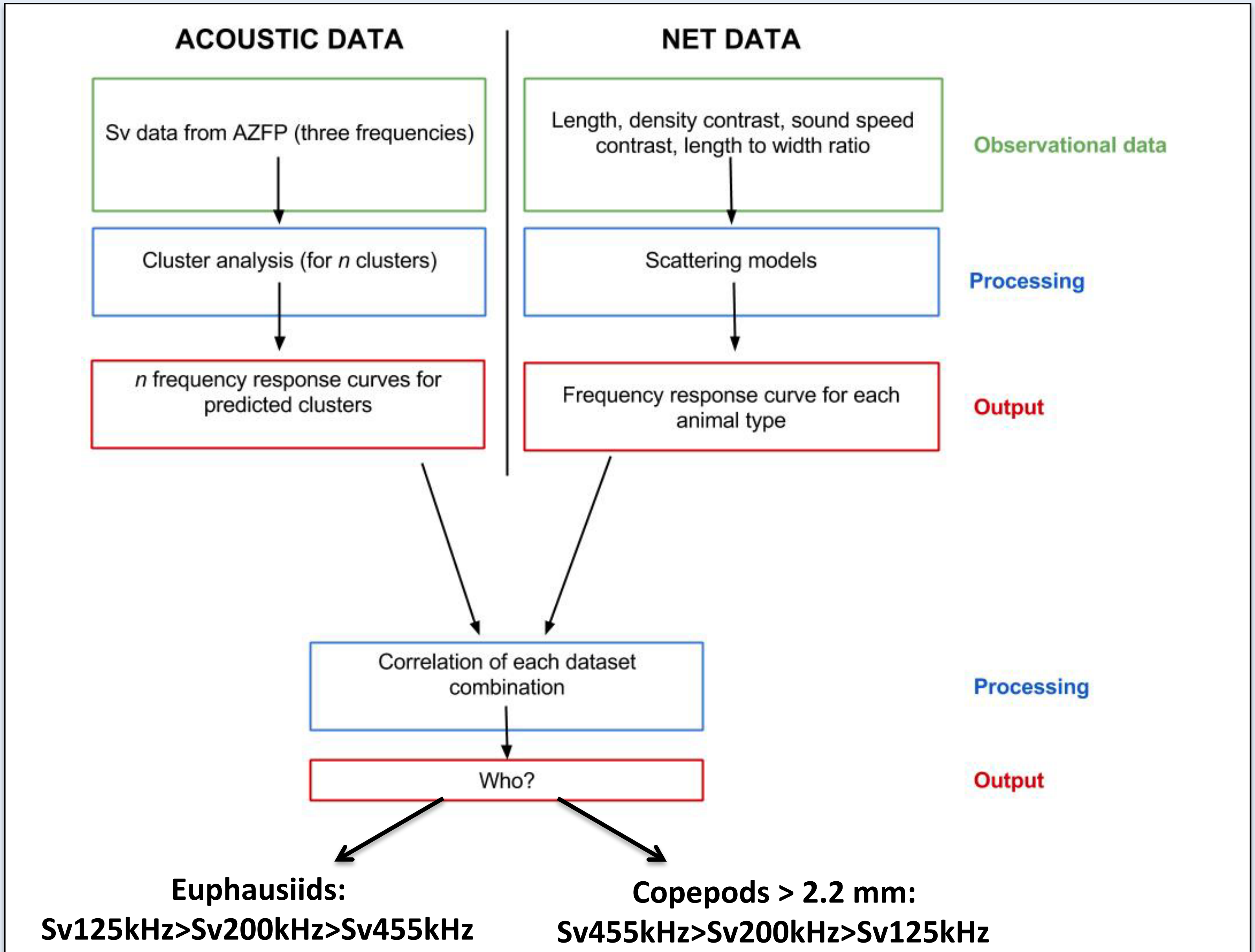
Multinet 200 µm



17 Jan to 9 Sep 2014



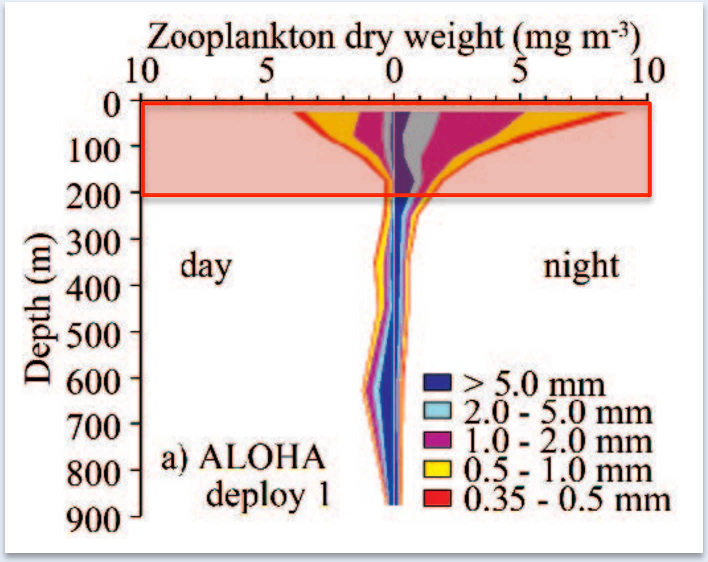
Acoustic Zooplankton Fish Profiler data analysis



(Hobbs 2014)

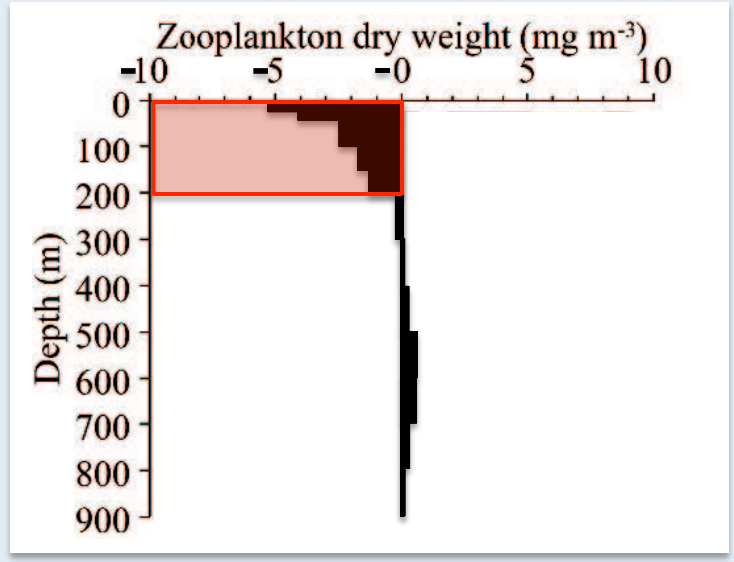
Calculation of daily fluxes due to DVM

Biomass profiles



(Steinberg et al. 2008, LNO)

Day-night (Δ) profile



Migrant biomass = $\int_{0\text{-}200m} \Delta$ biomass

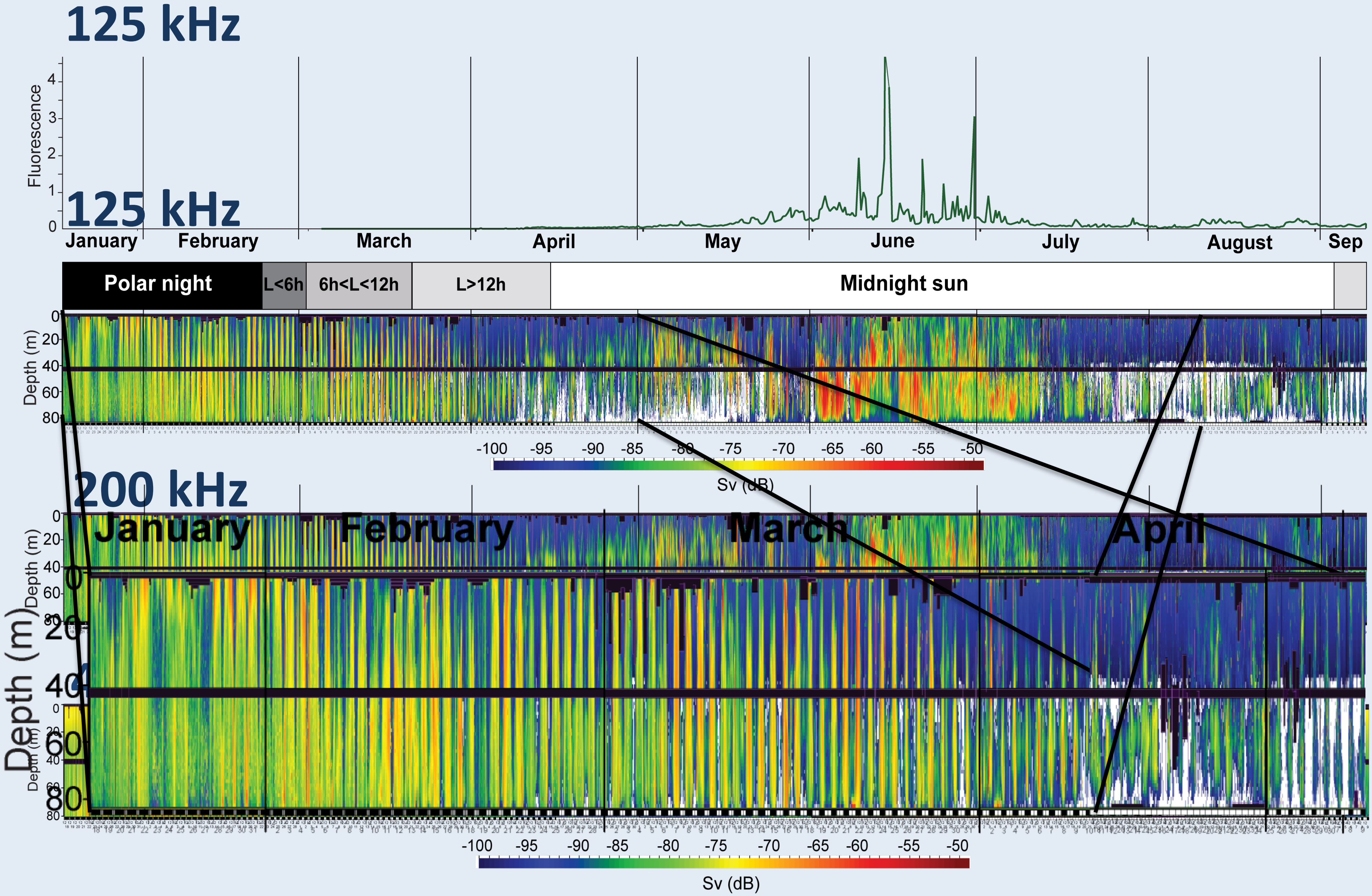
Resp. C flux = migrant biomass x resp per unit mass x time at depth

(mg C m^{-2} d^{-1}) (mg C m^{-2}) (mg C mg body C^{-1} h^{-1}) (h)

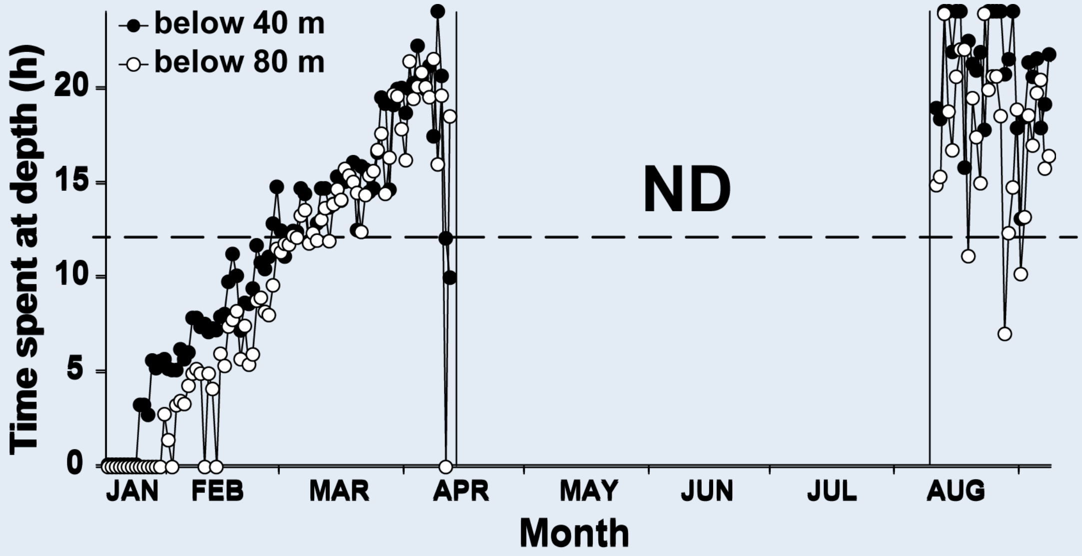
NH_4-N flux = migrant biomass x excr per unit mass x time at depth

(mg NH_4-N m^{-2} d^{-1}) (mg C m^{-2}) (mg NH_4-N mg body C^{-1} h^{-1}) (h)

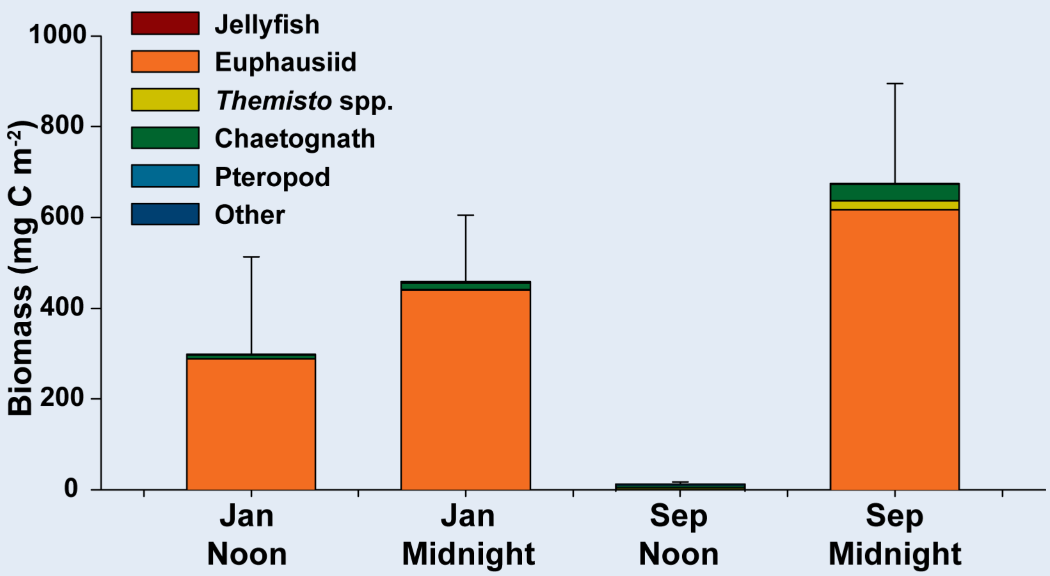
Seasonal variation in DVM pattern



Time at depth



Macrozooplankton composition from net catches

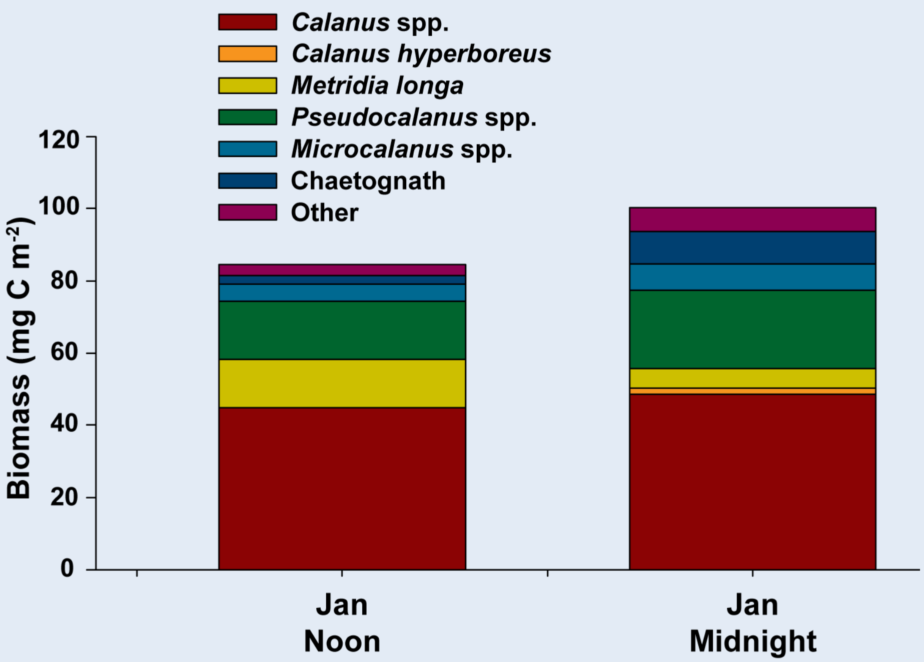


Jan: Euphausiids = 95% of macrozooplankton biomass at noon and midnight

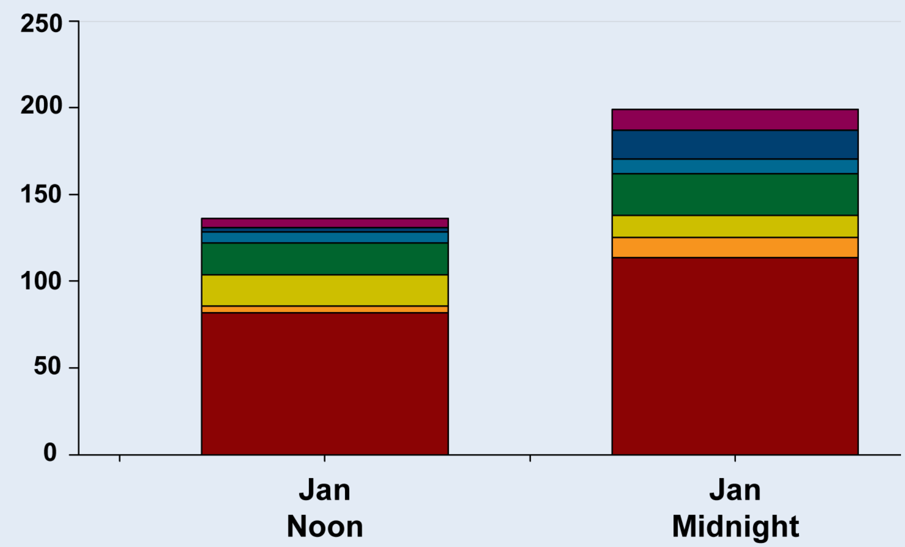
Sep: Euphausiids = 9% of macrozooplankton biomass at noon and 91% at midnight

Mesozooplankton composition from net catches

50-0 m



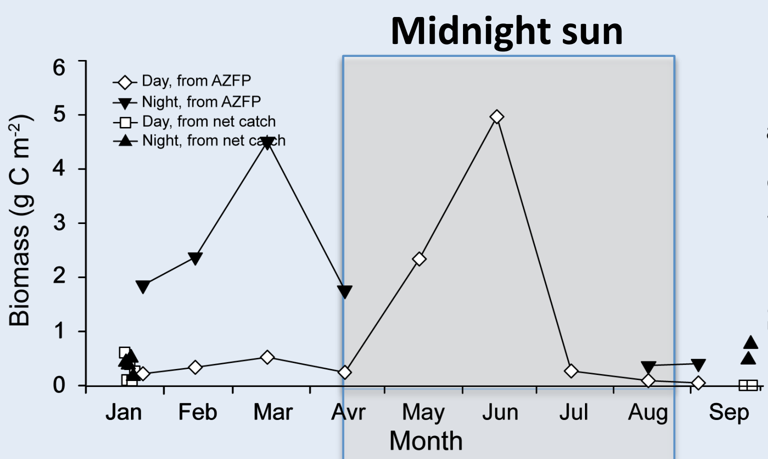
100-0 m



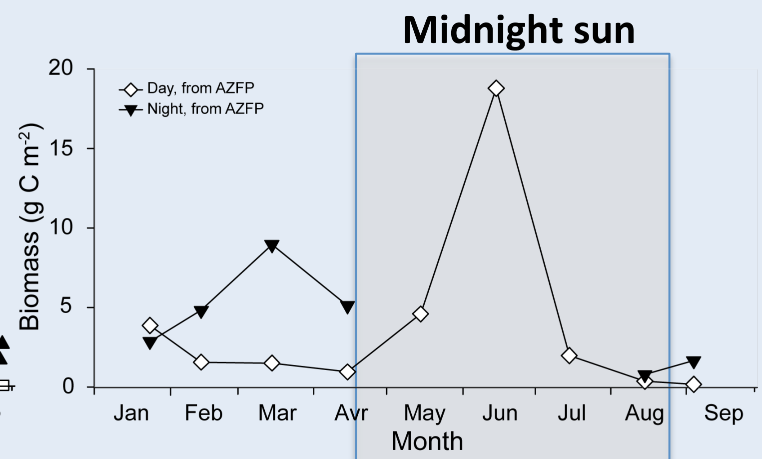
Large copepods (*Calanus* & *Metridia*) = 69-75% of mesozooplankton biomass at noon and midnight

Euphausiid migrant biomass

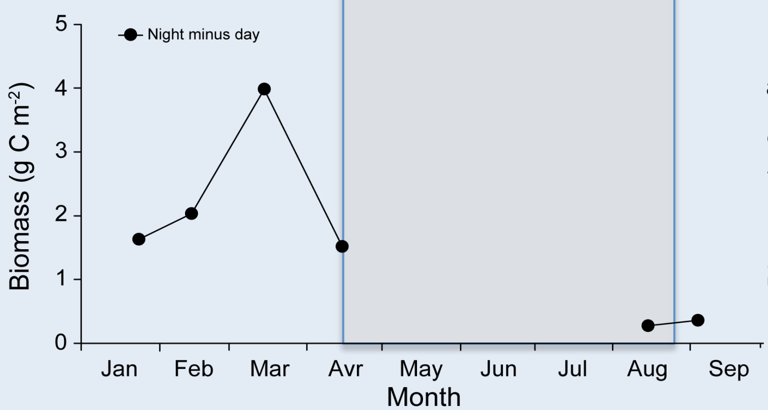
40-0 m

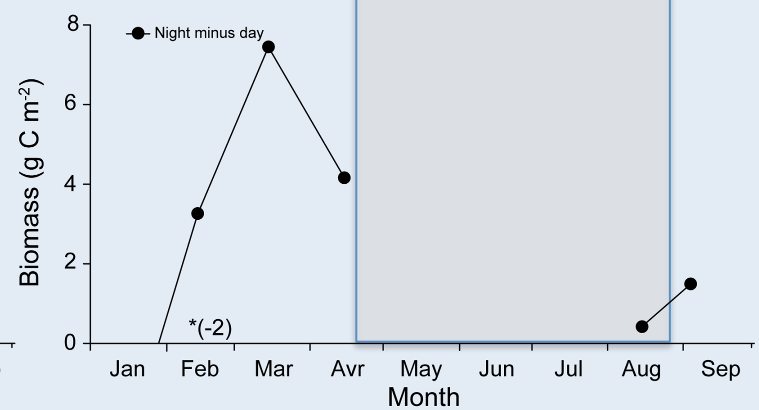


80-0 m



Migrant biomass

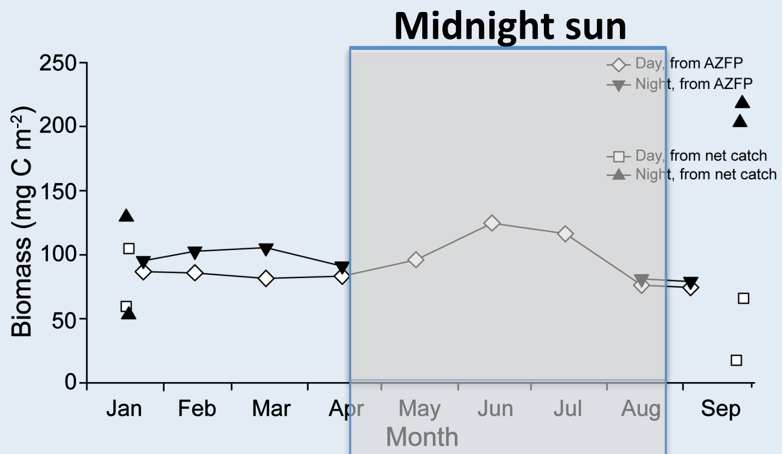


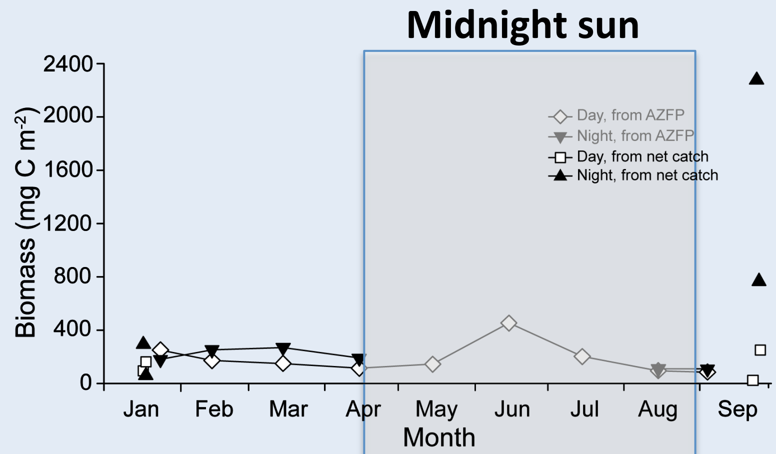


Copepod migrant biomass

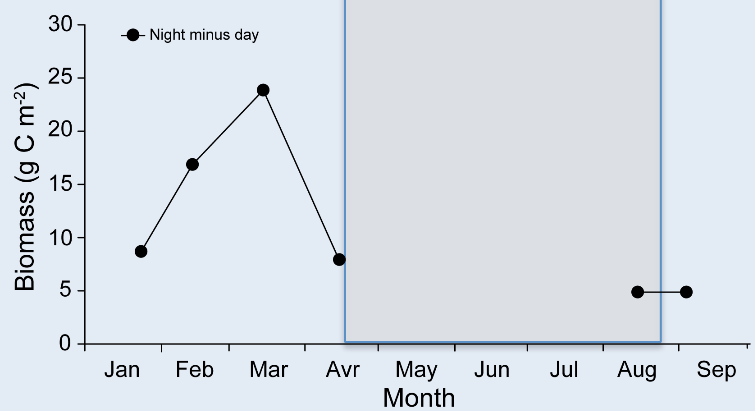
40-0 m

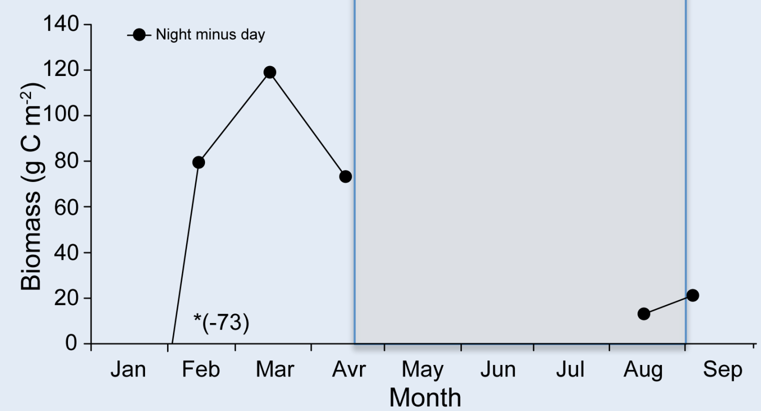
80-0 m



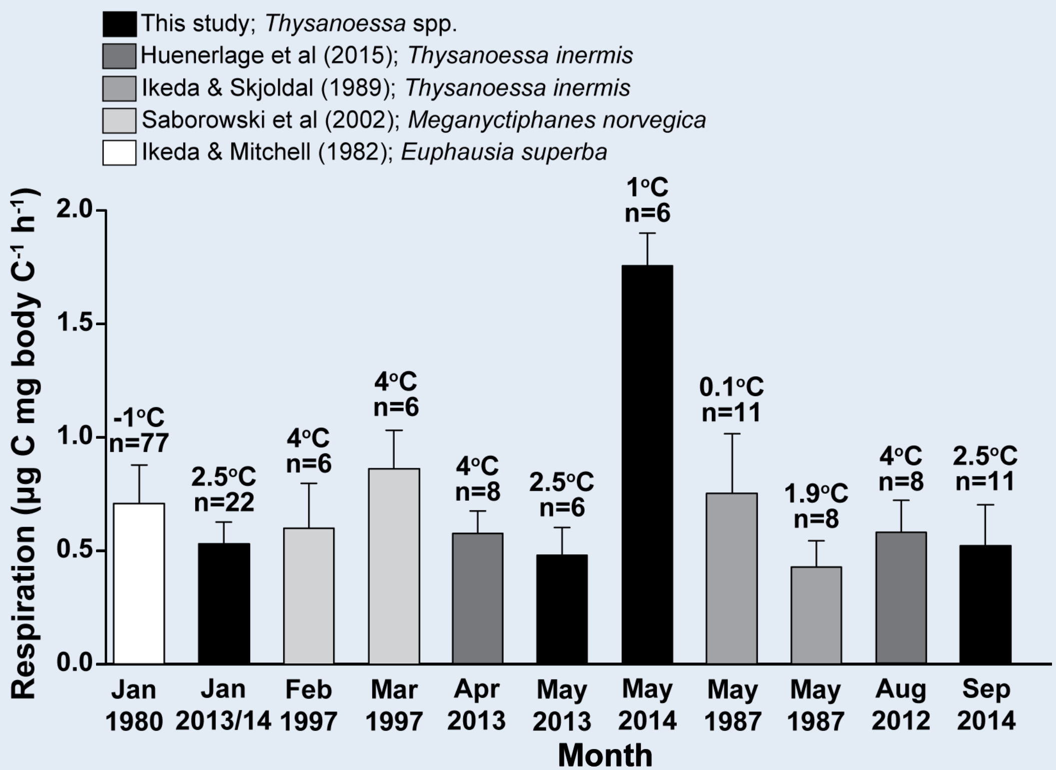


Migrant biomass

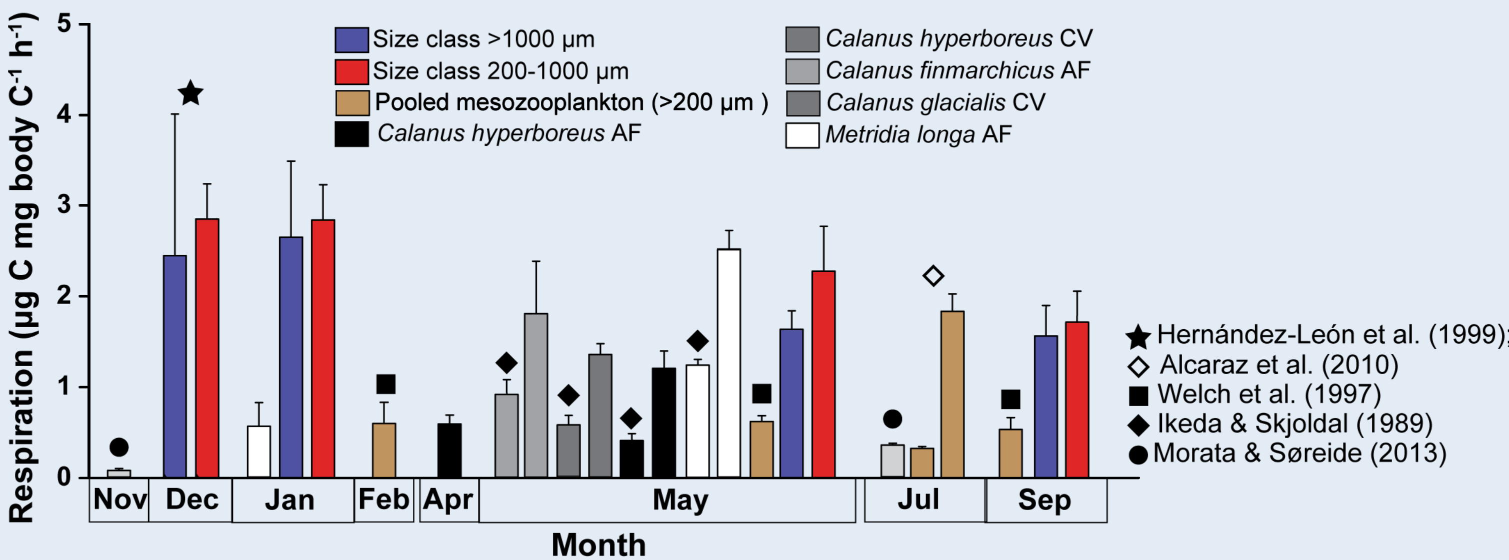




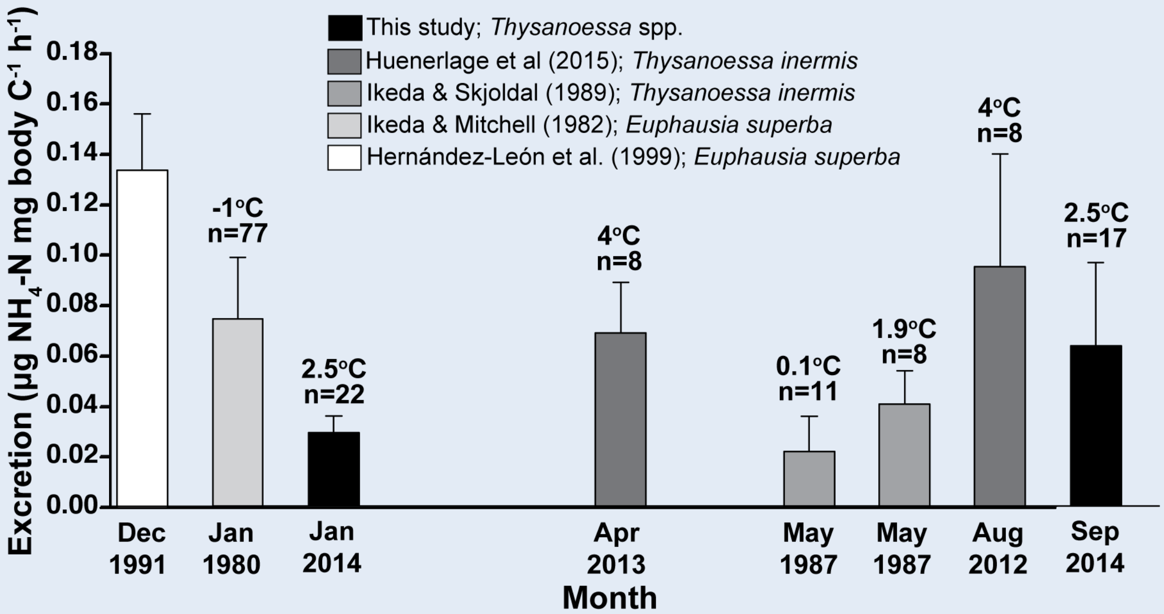
Euphausiid specific respiration



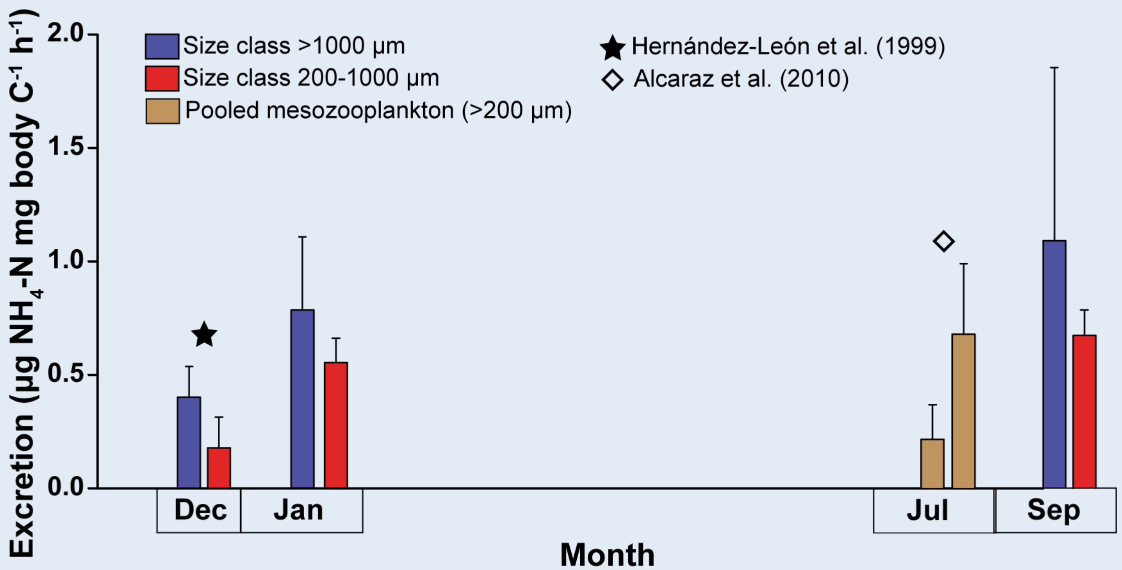
Mesozooplankton specific respiration



Euphausiid specific excretion

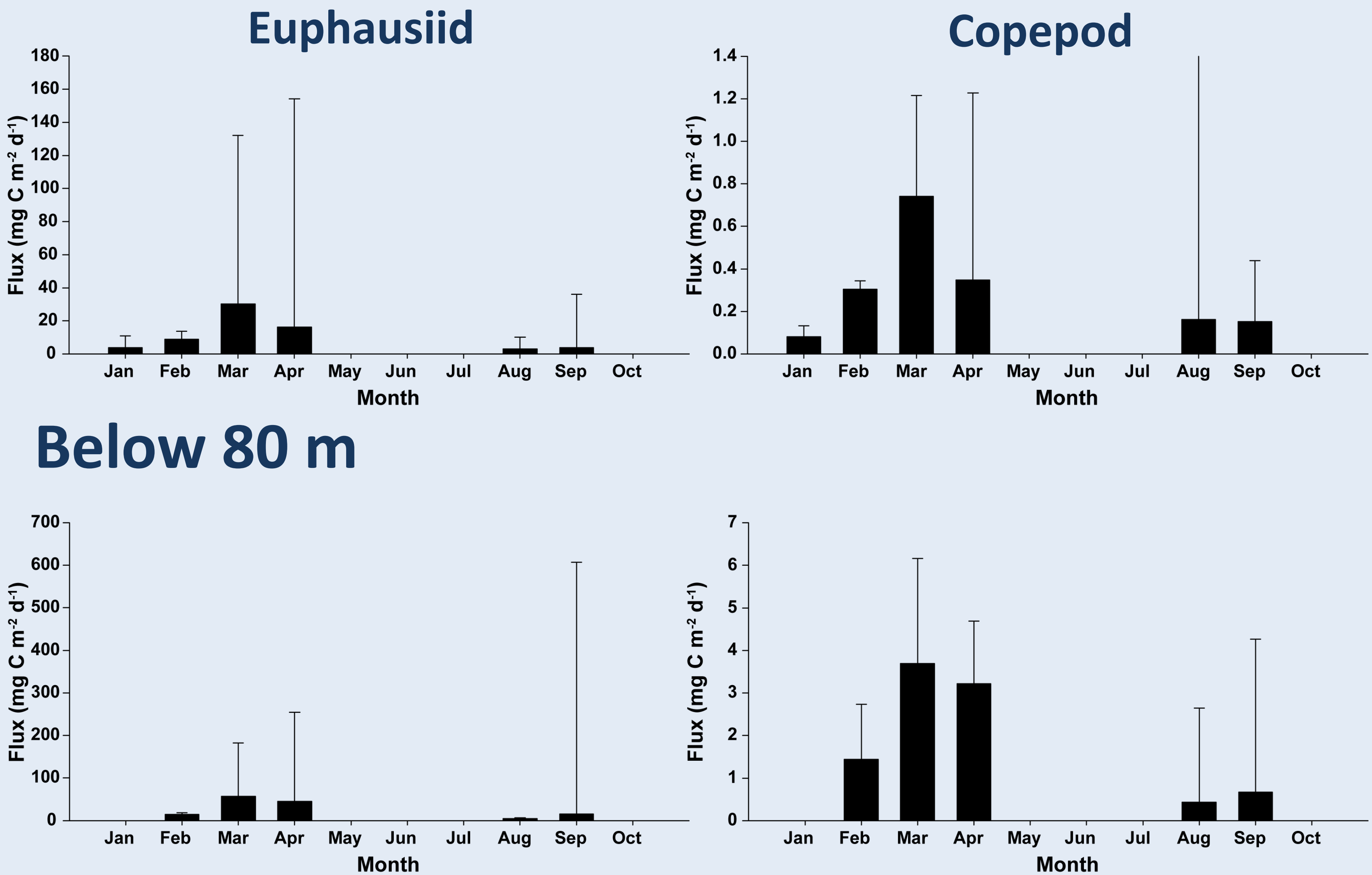


Mesozooplankton specific excretion



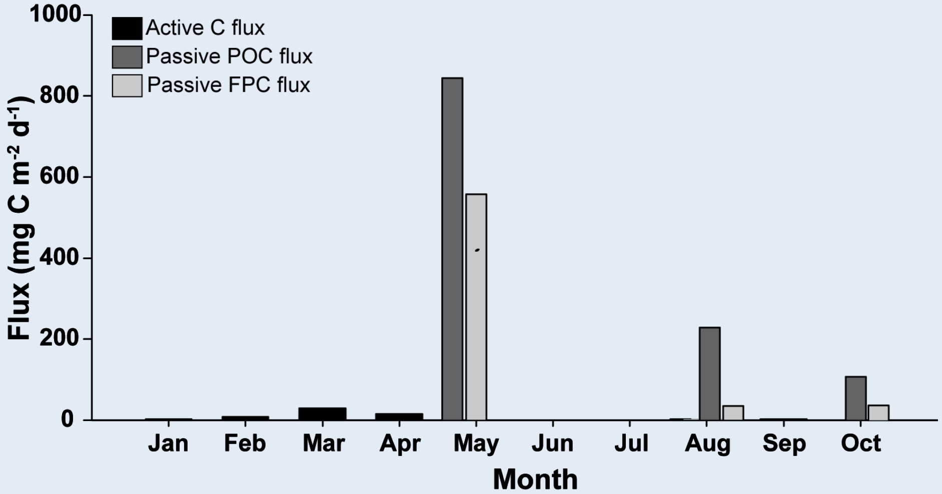
Active respiratory carbon flux

Below 40 m

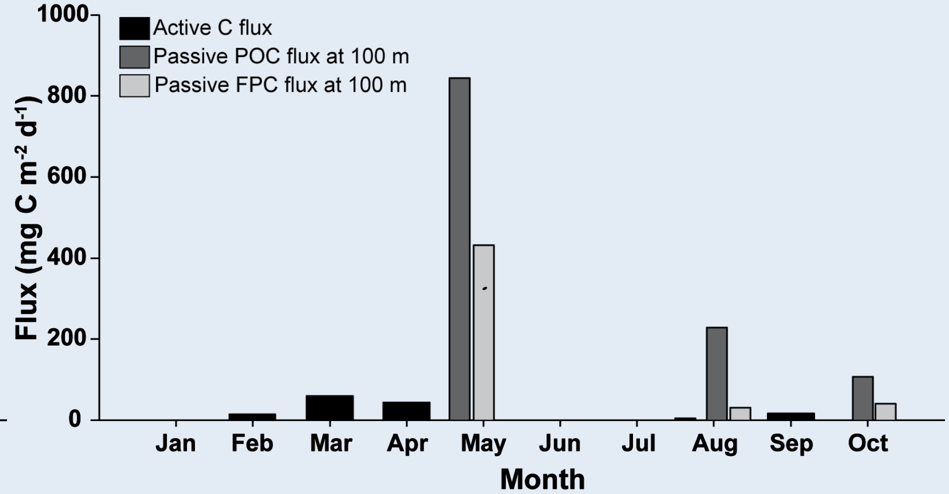


Active respiratory carbon flux versus passive flux

Below 40 m



Below 80 m



Respiratory carbon flux

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Western Equator	160	367 (144-447)	22.7 (7.3-19.1)	**13-35**	8
Svalbard-Macro	**40**	**2292 ± 1150**	**13.2 ± 11.5**	**-**	
Svalbard-Macro	**80**	**4955 ± 2200**	**25.6 ± 23.6**	**-**	
Svalbard-Meso	**40**	**14 ± 8**	**0.36 ± 0.28**	**-**	
Svalbard-Meso	**80**	**91 ± 25**	**1.53 ± 1.67**	**-**	

Active nitrogen flux due to zooplankton DVM

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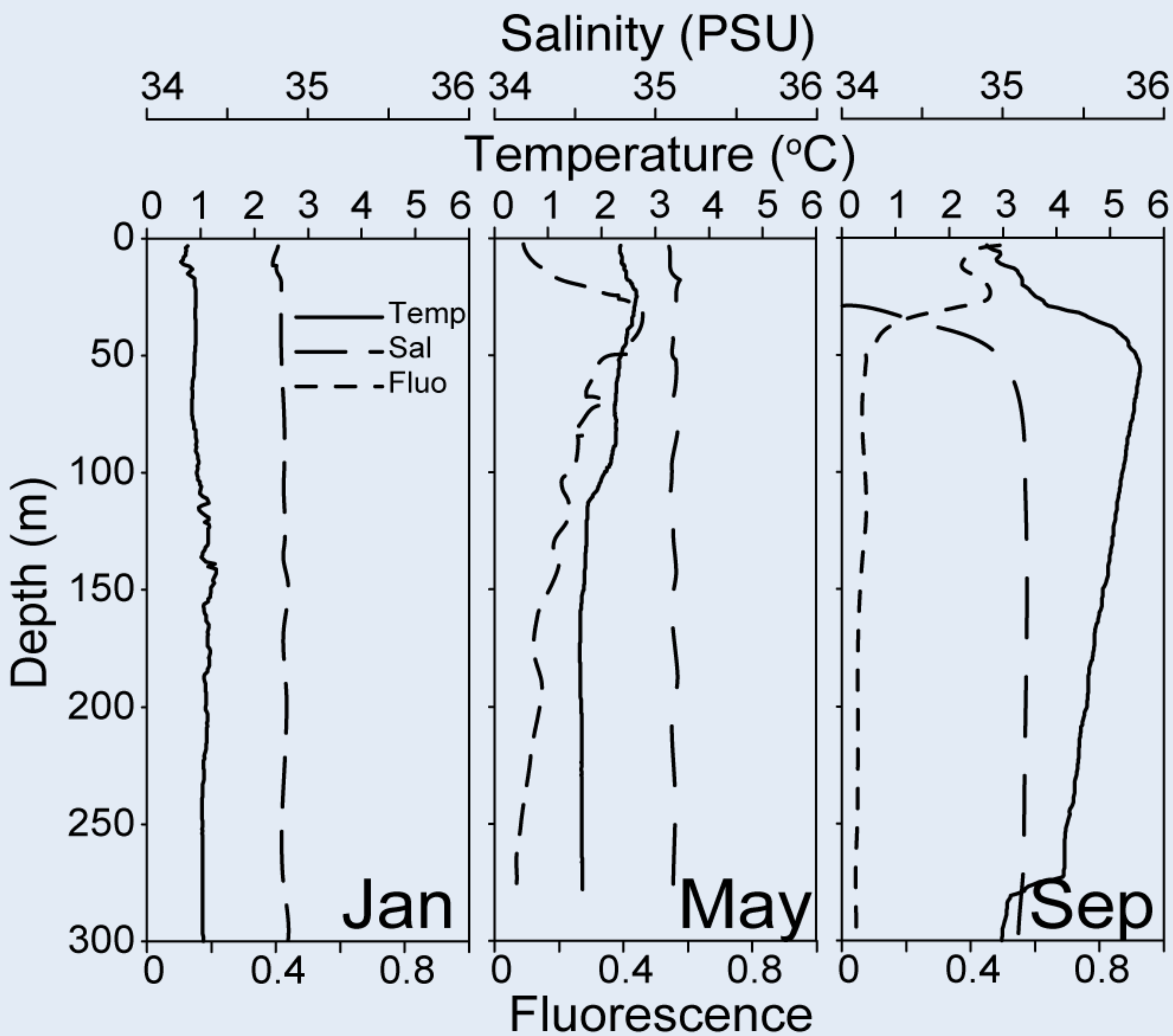
Equat. Pacific	200	8	3.6	**45**	6
Svalbard-Macro	**40**	**-**	**0.8 ± 0.6**	**-**	
Svalbard-Macro	**80**	**-**	**1.6 ± 1.3**	**-**	
Svalbard-Meso	**40**	**-**	**0.11 ± 0.12**	**-**	
Svalbard-Meso	**80**	**-**	**0.51 ± 0.65**	**-**	

[1]Longhurst et al (1989); [2]Rodier & Le Borgne (1997); [3]Steinberg et al (2002); [4]Al Mutairi & Landry (2001); [5]Dam et al. (1995); [6]Le Borgne and Rodier (1997)

Profiles



Salinity (PSU)
34
35
36
Temperature (°C)
0 1 2 3 4 5 6
Depth (m)
0
50
100
150
200
250
300
Temp
Sal
Fluo
Jan
May
Sep
0
0.4
0.8
Fluorescence

Summary

- **Euphausiids (*Thysanoessa* spp.) and large copepods make synchronous DVM between polar night and start of midnight sun.**
- **Migrant biomass of krill 32- 192 times larger that migrant biomass of copepods.**
- **Highest migrant biomass in March, when day-night light difference is strongest.**
- **Carbon and nitrogen active transport on a diel basis is extremely variable due to high migrant biomass variability.**
- **Classical DVM and dependent fluxes stop before the season of high biological production (spring-summer bloom).**
- **The relative importance of active carbon transport below 40 m and 80 m compared to POC flux or fecal pellet carbon flux is not well documented in this study.**

Conclusion

- Euphausiids *Thysanoessa* spp. main responsible for the winter strong synchronous DVM patterns, and possibly the high biomass in June 2014.
- Low migrant biomass of copepods involved in DVM.
- Classic synchronous DVM, and associated respiratory carbon flux, uncoupled from primary production in Kongsfjorden in 2014.
- Synchronous DVM not important for the export of carbon and nitrogen from the surface layer in high-arctic marine ecosystems; but what about asynchronous VM during the production season?
- Direction of carbon transport before PP sets in the photic layer.

Issues, fears and other stuff ?

- I'm in love with an AZFP.
- Conflict with other studies planned within CircA?
- No net data to validate summer zooplankton composition? Is the high June biomass observed with AZFP made of krill?
- Direction of the flux: upward or downward in winter? Study marine snow distribution with VPR data from January 2014?
- LNO or other top-shelf magazines?

Acknowledgments

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- Research Council of Norway (NFR)

Z team:

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- Daniel Vogedes
- Finlo Cottier
- Malin Daase
- Marina Sanz-Martin
- Stig Falk-Petersen
- Tove Gabrielsen
- Trine Callesen
- AB320/820 students...

Akvaplan-niva | Universitetet i Tromsø | CircA – Circadian rhythms of Arctic zooplankton | UNIS | SAMS

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CircA annual meeting, 1 Jun 2015, Oban