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Exploratory survey on the abundance and distribution of *Calanus finmarchicus* southwest of Iceland as a potentially harvestable resource / *Rannsóknir á þéttleika og dreifingu rauðátu,* Calanus finmarchicus*, suðvestan við Ísland með tilliti til veiðimöguleika*

Ástþór Gíslason, Hjalti Karlsson, Kurt Tande og Kristján G. Jóakimsson

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Upplýsingablað

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Ágrip

Dagana 7.-13. júní 2012 var farinn rannsóknaleiðangur á rannsóknaskipinu Dröfn á hafsvæðið suðvestur af Íslandi, bæði yfir landgrunninu og utan þess, til að kanna hvort þéttleiki rauðátu (*Calanus finmarchicus*) að vor- og sumarlagi væri nægur til að hægt væri að stunda veiðar á henni. Til rannsókna á útbreiðslu, lóðréttri dreifingu og þroska rauðátu voru tekin sýni með WP2-háfum og sérhönnuðum smáháfum („planktometer") sem notaðir voru til að ná sýnum á mismunandi dýpum (0, 5, 10, 15, 20, 30, 50 m). Á nokkrum stöðvum var auk þess notað sérstakt hringnet með þvermáli 1,6 m til að meta þéttleika rauðátu. Gögnum um hita og seltu sjávar var safnað á öllum stöðvum með sondu. Niðurstöður benda til að í fyrri hluta júní sé þéttleiki rauðátu nægur til að hægt sé að stunda veiðar á fjölmörgum stöðum suðvestur af landinu, einkum við landgrunns-brúnirnar. Seinni helmingur júní og júlí kunna að vera enn hentugri til veiða, því að þá hefur rauðátan væntanlega safnað meiri fituforða og meira af litarefninu astaxantín. Vestari hluti athugunarsvæðisins einkenndist af miklum og útbreiddum svifþörungavexti sem hamlaði rauðátuveiðunum. Lagt er til að frekari rannsóknir á veiðimöguleikum rauðátu verði gerðar í síðari hluta júní og í júlí yfir landgrunnsbrúnunum suður af landinu.

Abstract

An exploratory survey was carried out on the RV Dröfn 7-13 June 2012 to investigate the densities of Calanus finmarchicus *on the shelf and off-shelf areas southwest of Iceland, and assess if commercial harvesting of this species is feasible. The horizontal and vertical* *distribution of* C. finmarchicus *was studied using WP2 nets, a ring net and a "planktometer", which consists of a series of small nets towed simultaneously at different depths (0, 5, 10, 15, 20, 30, 50 m). In addition, hydrographic measurements were made at every station. Results indicate that during the first half of June the densities of* C. finmarchicus *are sufficiently high for commercial harvesting in several areas south of Iceland, especially near the shelf breaks. There are indications that the latter half of June and early July may be more favourable time for harvesting, as* C. finmarchicus *may have accumulated more fat and astaxanthin. The westernmost regions were characterized by a massive phytoplankton bloom that had wide coverage and that hampered harvesting* Calanus*. Future work should focus on the distribution and abundance of* C. finmarchicus *during the latter half of June and first part of July near the shelf break regions in south.*

Lykilorð: *Rauðáta, veiðar, Calanus finmarchicus, harvesting, Iceland*

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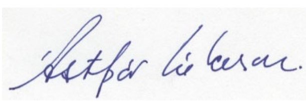	

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Introduction

In Icelandic waters, as elsewhere in the North Atlantic, the copepod *Calanus finmarchicus* dominates the mesozooplankton community (Astthorsson *et al.* 1983, Conover 1988, Gislason 2005). Investigations on the biomass distribution and egg production rates of *C. finmarchicus* around Iceland indicate that the warmer waters off the south and west coasts provide a more favourable environment for the growth and development of *C. finmarchicus* than the colder waters off the north coast (Gislason 2005).

C. finmarchicus contains high amounts of Omega-3 fatty acids and can therefore be important as ingredient in aquaculture feed (Eysteinsson *et al.* 2018). However, its potential as ingredient in health and nutrient products and bioactive compounds may be even higher (Höper et al. 2013, 2014, Jansen et al. 2019, Schots et al. 2020, review in Eysteinsson *et al.* 2018). Several publications relevant for this work are also available by Professor Terje Larsen at UiT, The Arctic University of Norway.

The mean annual biomass of *C. finmarchicus* within the Icelandic 200-mile exclusive economic zone has been estimated to be about 7 million tons wet weight (Astthorsson et al 2007). Based on this and information on the life cycle of the species, the annual production may be estimated as around 30 million tons wet weight, which is about 15 times higher than the total annual catch of all fish species in Icelandic waters. Hence, there is a growing interest for commercial exploitation of *C. finmarchicus* in Icelandic waters as elsewhere (Eysteinsson *et al.* 2018).

The aim of the survey was to investigate if densities of *C. finmarchicus* southwest of Iceland during spring were sufficiently high to make commercial harvesting profitable. The project was a collaborative effort of the Marine Research Institute, Iceland, Hraðfrystihúsið Gunnvör Ltd., Hnífsdalur, Iceland, and Calanus AS, Tromsö, Norway.

Methods

Survey design and sample operations

The survey was designed around a pelagic survey track southwest of Iceland with stations approximately 20 nm apart (Figure 1). At every station a CTD was deployed down to 100 m or ~5 m from the bottom where bottom depth was less than 100 m, and plankton samples were taken at different depths with a “planktometer”, a series of 7 small nets (diameter 15 cm, 500 µ mesh) that were successively attached to a wire cable at intervals so as keep the nets at approximately 0, 5, 10, 15, 20, 30, 50 m depths during the tow. A weight was attached at the end of the wire cable to keep the suspended wire at an angle of about 10-45 degrees. The series of nets was towed for 15 minutes while the ship cruised at slow speed (~1 knot). At approximately every other station, two vertical tows were made with a WP2 net (200 µ), from 50 m and 100 m depths and to the surface. At 3 stations, a ring net (1.6 m diameter, 475 µ mesh) was towed vertically for 30 to 60 minutes while the ship cruised at slow speed (~1-2 knots).

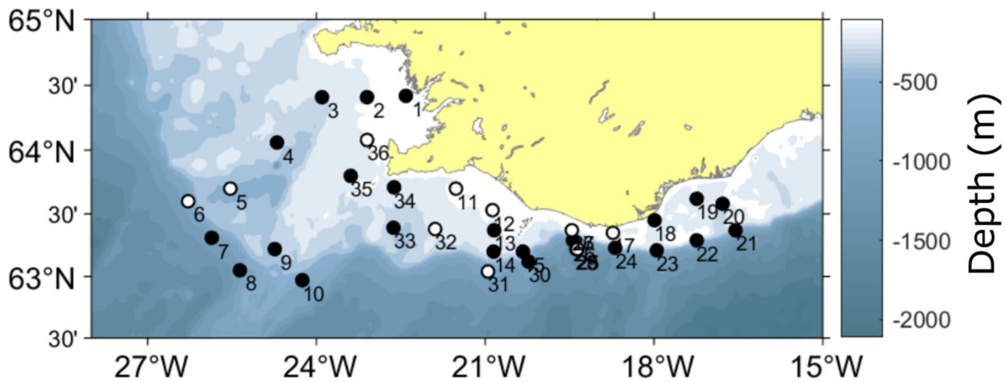

Figure 1. Map showing location of stations. Stations where the planktometer catches indicated that biomass of Calanus finmarchicus *was sufficient for commercial harvesting are indicated by white dots.*

The displacement volumes of the "planktometer" and WP2 net catches were measured on board. The data from the planktometer were used to evaluate if biomass was sufficient for commercial harvesting by the harvesting methods used by Calanus AS. The criteria were that average biomass in volume for all nets was >4 ml, and that biomass in at least one depth was >5 ml. In addition, the magnitude of phytoplankton growth at the station was also considered. The WP2 net samples were preserved in 4% buffered formalin. In the laboratory ashore they were analysed according a "short-cut" method, where a random subsample of approximately 150-300 animals were identified and counted, and *Calanus* allocated to developmental stages. In all, 17 species and groups were identified and counted. The displacement volumes of the WP2 net catches were converted to dry weight using the conversion 1 ml displacement volume = 0.13 g dry weight. Subsamples of the ring net catches were frozen for later analyses with respect to chemical composition and by-catch.

Cruise narrative

The RV Dröfn departed from Reykjavik at 11:30 on 7 June 2012 heading for the first station located in the inner part of the bay of Faxaflói (Table 1). On the station we deployed the CTD and towed the planktometer and the WP2 as described in the previous section. We then sailed further west and southwest and sampled stations in the manner described above (Table 1). The night before 9 June, after having completed Stn 10, we had to terminate station operations because of bad weather and the course was set to Grindavík. We called harbor in Grindavík at ~16:00 on 9 June and stayed there until 07:00 the following morning when we left harbour again when the weather had improved. We then worked eastward along the shelf areas south of Iceland taking stations on the way as described above. We reached the easternmost station on 11 June in the afternoon, thereafter we worked westwards in the deeper areas (Figure 1). We completed the last station located west of Garðskagi in the afternoon of 13 June 2012 and returned to port in Reykjavik at around 18:30 the same day.

Results and Discussion

Hydrography

Figure 2 shows distribution of average temperature and salinity in surface layers (0-50 m). Temperatures and salinities were generally highest south of Iceland, reflecting the southern origin of the relatively warm and saline Atlantic Water. Close to the coast southwest of Iceland and in Faxaflói, temperatures and salinities were lower reflecting freshwater efflux from rivers (Figure 2A). Thus, typical early summer conditions prevailed in the study area.

At several station off the west coast (e.g., Stns, 2, 3, 4, 5, 6, 8, 9, Figure 1) a massive phytoplankton bloom was observed.

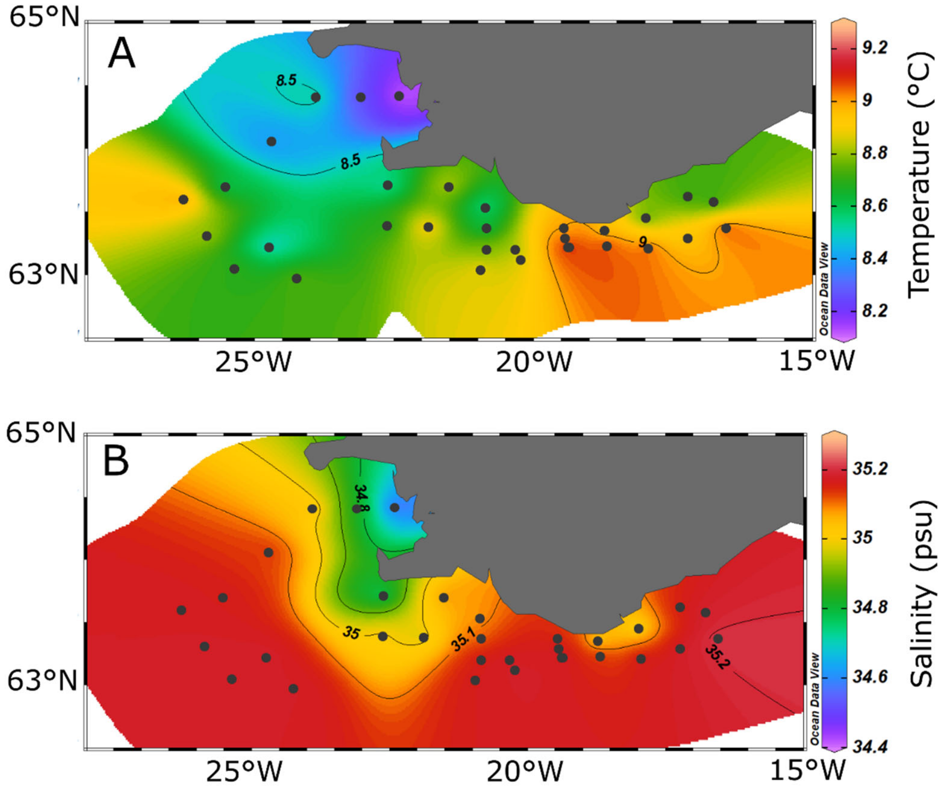

Figure 2. Distribution of average temperature (A) and salinity (B) at 0-50 m depth southwest of Iceland 7-13 June 2012. Black dots indicate stations.

Distribution of zooplankton

Integrated mesozooplankon biomass was much higher in the 0-50 m depth layer (range 1-13 g dw m^{-2}) than in the 50-100 m layer (0-4 g dw m^{-2}) (Figure 3). Biomass was generally highest over the shelf areas in south and west (~5-15 g dw m^{-2}, 0-50m). In the more offshore areas near the shelf breaks in south and southwest biomass was lower (~2-10 g dw m^{-2}, 0-50m) (Figure 3).

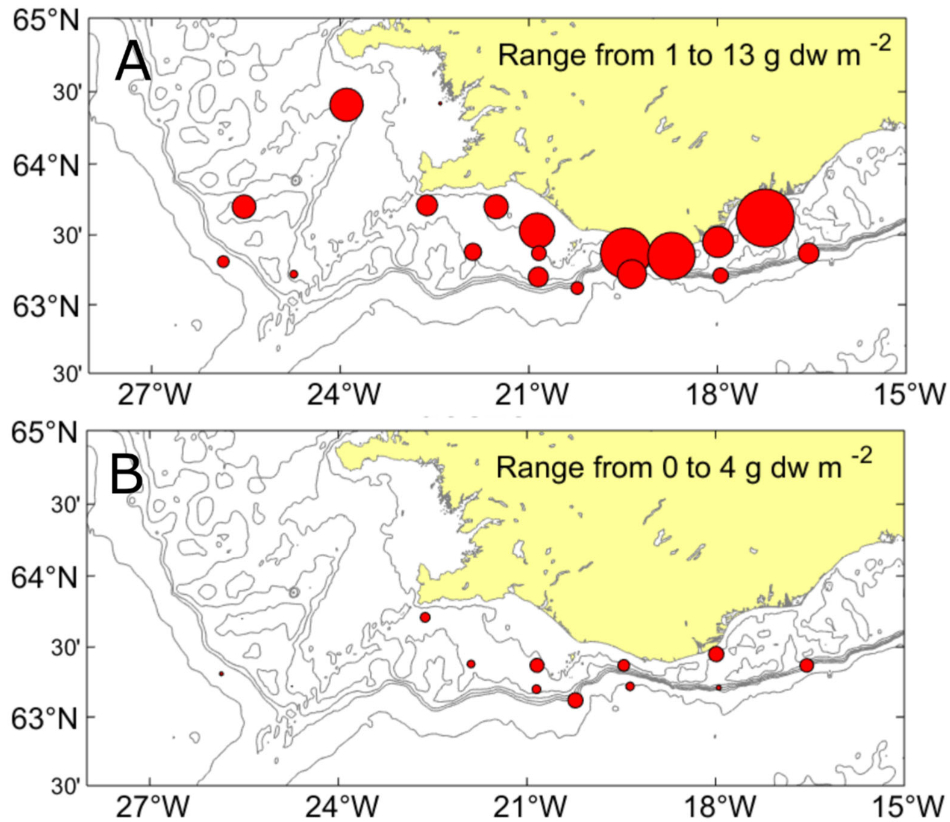

Figure 3. Distribution of mesozooplankton biomass (g dw m^{-2}) at 0-50 m depth (A) and at 50-100 m depth (B). Biomass values for 50-100 m were obtained by subtracting biomass in 0-50 m from biomass in 0-100 m. Depth contours are shown for 100, 200, 300, 400, 500, 1000 m.

Figure 4 shows integrated biomass of mesozooplankton in two depth layers (0-50 m and 0-100 m) as average values for all stations. Comparison of the catches of zooplankton in these two depth layers shows that ~75% of the plankton was found in the upper 50 m. Thus, it is evident that the stocks have surfaced from overwintering depths.

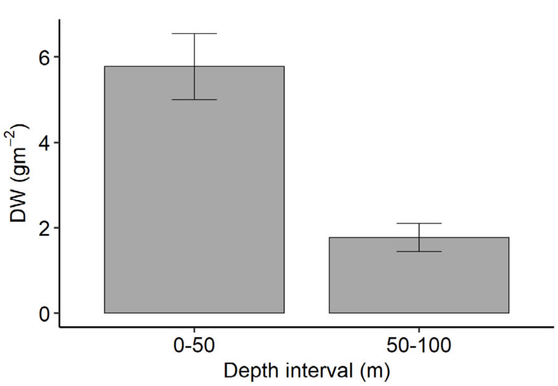

Figure 4. Integrated average biomass of mesozooplankon sampled by WP2 nets in two depth layers southwest of Iceland 7-13 June 2012. The data are mean values from 15 stations. Error bars show standard error.

Calanus *development*

Calanus nauplii were found predominantly on the shelf in the southeast and southwest (Figure 5). The youngest copepodite stages (C1-3) were found predominantly over the shelf in the south and near the shelf edge in southwest. As judged by the distribution pattern of the young stages, vigorous growth of *Calanus* was taking place on the shelf. The older copepodite stages (C4-6) had a somewhat more offshore distribution than the juveniles, possibly indicating that the older individuals were being transported by the inflow of Atlantic Water from the oceanic area and onto the shelf (Figure 5).

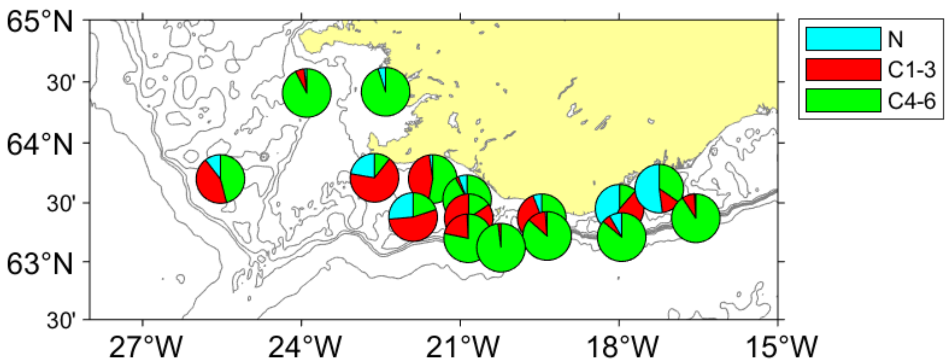

Figure 5. Percent frequency of developmental stages of C. finmarchicus *southwest of Iceland 7-13 June 2012; nauplii (A), C1-C3 (B) and C4-6 (C). Depth contours are shown for 100, 200, 300, 400, 500, 1000 m.*

Potential for harvesting Calanus *commercially*

Stations where the planktometer catches indicated that biomass of *Calanus* was sufficiently high for commercial harvesting is shown on Figure 1. This threshold (see definition above) is based on the harvesting technology used by Calanus AS at that time in Norwegian coastal waters. These regions coincide with regions where *Calanus* was growing fast and where the proportion of older stages (C4-6) was relatively high (compare Figures 1 and 5). The areas near the shelf break in the Háfadýpi region (at around 19'30°W) appear particularly promising as the biomass of zooplankton (dominated by *Calanus*) was also highest there (Figure 3).

The relatively high proportion of juvenile stages indicates that significant growth was still taking place. Therefore, the latter half of June and early July may be even a more favourable time for harvesting *Calanus* south of Iceland than the time of the present study (early June), as the animals may then have accumulated more fat and astaxanthin, and the small stages advanced to stage C4/C5. Bycatch of fish eggs and larvae (see below) can also be expected to be less at that time considering the main spawning time of the species spawning there.

The massive phytoplankton bloom observed at some of the western stations (e.g., Stns, 2, 3, 4, 5, 6, 8, 9, Figure 1) hampered fishing for *Calanus* by the planktometer and the WP2 net.

Within the upper 50 m depth layer, biomass appeared on average highest at 15 m depth indicating that this is generally the most feasible depth for harvesting (Figure 6, Appendix 4).

However, there was considerable variability in the depth distribution between stations and on several stations highest biomass was observed either above or below this depth. The sampling for this study took place during the time of the midnight sun in Iceland and was mainly carried out during daytime. Diurnal shifts in vertical distribution of biomass are known from the literature to occur within the upper 50 m depth layer during summer. However, diel migrations are probably minimal during the time of the midnight sun.

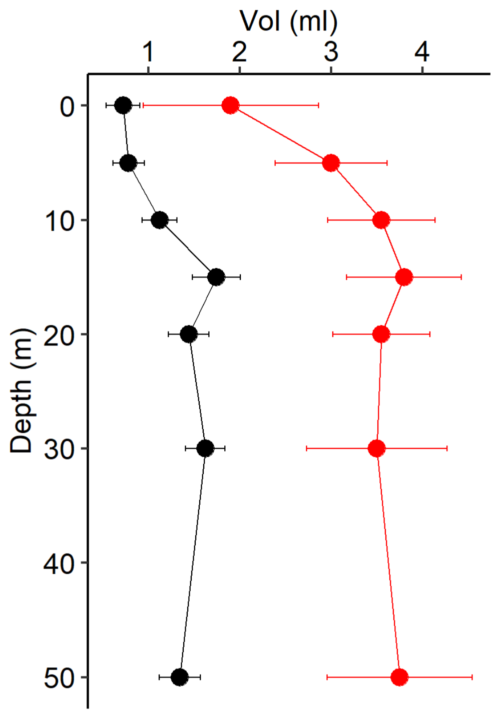

Figure 6. Depth distribution of Calanus finmarchicus *biomass (volume caught by net in 15 minutes tow) as indicated by the planktometer. Black dots show average values from 25 stations where biomass was low so not harvestable, red dots show average values from 10 stations where the catch was sufficient for commercial harvesting. Error bars are SE.*

Bycatch

The survey covered the Selvogsbanki region where the main spawning grounds of fish species of commercial values are located, such as the Icelandic cod and haddock. It is therefore of interest to study the abundance of fish eggs and fish larvae in the samples taken.

In the WP2 net samples, neither fish eggs nor fish larvae were found.

Ring net-samples from three stations (Stns 29, 31, 35, Figure 1) were analysed with respect to presence of fish eggs and fish larvae. Subsamples from around one third of the total samples were analysed, but no fish eggs were found. At Stns 29 and 31, only a few fish larvae were found in the samples (~10-15 fish larvae per tow hour), whereas at Stn 35, the estimated number of fish larvae was much higher (~340 larvae per tow hour). The fish larvae were not identified to species.

Table 1. Bycatch of fish larvae in ring net catches. Total catch consists mainly of Calanus finmarchicus. Proportion analysed is by weight.

Stn	Towing time (min)	Total catch (kg)	Proportion analysed	Number of fish larvae per towing hour
29	60	1	0.014	14
31	60	5	0.098	10
35	30	1	0.171	339

Stns 29 and 31 are located over the shelf edge south or southeastward of the main spawning grounds of fish and outside the main drift route of fish eggs and fish larvae. Stn 35, on the other hand, is located in shallow water west of Reykjanes on the main drift route of fish eggs and fish larvae (Figure 1). The finding of an elevated abundance of fish larvae in the samples taken there is therefore not unexpected.

Conclusions

Considering the high biomass and production of the stocks of *C. finmarchicus* off Iceland, it is unlikely that limited harvesting of *C. finmarchicus* will affect the marine ecosystem.

The months of June and July are favourable time for harvesting *Calanus* south and west of Iceland.

If commercial harvest should be tried out in these waters during the summer period, it should be paralleled by bycatch analysis for fish eggs and larvae.

Acknowledgements

This research was supported by Hraðfrystihúsið Gunnvör Ltd., Hnífsdalur, Iceland, and Calanus AS, Tromsö, Norway. We thank Dr James Kennedy for correcting the English.

References

Astthorsson, O. S., Hallgrimsson, I., Jonsson, G. (1983). *Variations in zooplankton densities in Icelandic waters in spring during the years 1961-1982*. Rit Fiskideildar, 7: 73-113.

Astthorsson, O. S., Gislason, A., and Jonsson, S. (2007). Climate variability and the Icelandic marine ecosystem. *Deep-Sea Research II*, 54: 2456–2477.

Conover, R. J. (1988). Comparative life histories in the genera *Calanus* and *Neocalanus* in high latitudes of the northern hemisphere. *Hydrobiologia*, 167/168: 127-142.

Eysteinsson, S, Th., Gudjonsdottir, M., Jonasdottir, S. H., Arason, S. (2018). Review of the composition and current utilization of *Calanus finmarchicus* – Possibilities for human consumption. *Trends in Food Science and Technology*. 79: 10-18.

Gislason, A. (2005). Seasonal and spatial variability in egg production and biomass of *Calanus finmarchicus* around Iceland. *Marine Ecology Progress Series*, 286: 177–192.

Höper, A. C., Salma, W., Khalid, A. M., Hafstad, A. D., Sollie, S. J., Raa, J., Larsen, T., Aasum, E. (2013). Oil from the marine zooplankton *Calanus finmarchicus* improves the cardiometabolic phenotype of diet-induced obese mice. *British Journal of Nutrition*, 110: 2186-2193.

Höper, A. C., Salma, W., Sollie, S. J., Hafstad, A. D., Lund, J., Khalid, A. M., Raa, J., Aasum, E., Larsen, T. (2014). Wax esters from the marine copepod *Calanus finmarchicus* reduce diet-induced obesity and obesity-related metabolic disorders in mice. *Journal of Nutrition*, 144: 164-169.

Jansen, K., Moreno, S., Garcia-Roves, P. M., Larsen, T. (2019). Dietary calanus oil recovers metabolic flexibility and rescues postischemic cardiac function in obese female mice. American Journal of Physiology. *Heart and Circulatory Physiology*, 317: 290-299.

Schots, P. C., Pedersen, A. M., Eilertsen, K.-E., Olsen, R. L., Larsen, T. (2020). Possible Health Effects of a Wax Ester Rich Marine Oil. *Frontiers in Pharmacology*, 11: 1663-9812.

Appendices

Appendix 1: Table. Personnel

Scientific Personnel

Name	Role	Affiliation
Ástþór Gíslason	Cruise leader	MRI
Hjalti Karlsson	Zooplankton	MRI
Kurt Tande	Zooplankton	Calanus AS

Ship's Personnel

Name	Role	Affiliation
Gunnar Jóhannsson	Master	RV Dröfn
Ásgeir Guðbjartsson	Chief Officer	RV Dröfn
Rúnar Jónsson	Chief Engineer/Chef	RV Dröfn
Ólafur Haraldsson	Seaman	RV Dröfn
Sigurður A. Kristinsson	Seaman	RV Dröfn

Appendix 2: Figure. Crew members and scientific personnel

Figure. Crew members and scientific personnel (from left): Hjalti Karlsson, Ólafur Haraldsson, Ásgeir Guðbjartsson, Gunnar Jóhannsson, Ástþór Gíslason, Sigurður A. Kristinsson, Kurt Tande. Rúnar Jónsson is missing.

Appendix 3: List of stations and activities (D06-2012)

Stn	Day	Mon	Time	Lat (N)	Long (W)	Depth (m)	Activity
1	7	6	14:25	6424.97	-2224.84	52	CTD, WP2, planktometer
2	7	6	17:19	6424.58	-2306.09	116	CTD, planktometer
3	7	6	20:31	6424.30	-2353.80	202	CTD, WP2, planktometer
4	8	6	12:55	6403.66	-2441.80	256	CTD, planktometer
5	8	6	05:35	6342.25	-2531.87	387	CTD, WP2, planktometer
6	8	6	09:00	6336.16	-2616.56	363	CTD, planktometer
7	8	6	12:05	6318.42	-2551.61	431	CTD, WP2, planktometer
8	8	6	16:00	6303.26	-2521.65		CTD, planktometer
9	8	6	19:45	6313.37	-2444.16	285	CTD, WP2, planktometer
10	8	6	23:30	6258.07	-2415.24	300	CTD, planktometer
11	10	6	11:01	6342.11	-2131.03	108	CTD, WP2, planktometer
12	10	6	14:05	6331.99	-2052.24	81	CTD, WP2, planktometer
13	10	6	16:05	6321.94	-2050.69	114	CTD, WP2, planktometer
14	10	6	18:16	6311.70	-2050.84	182	CTD, WP2, planktometer
15	10	6	20:55	6311.81	-2019.62	180	CTD, planktometer
16	11	6	00:37	6322.47	-1927.61	105	CTD, WP2, planktometer
17	11	6	04:20	6320.74	-1843.92	117	CTD, WP2, planktometer
18	11	6	08:00	6326.91	-1759.63	99	CTD, WP2, planktometer
19	11	6	12:00	6337.32	-1714.52	165	CTD, WP2, planktometer
20	11	6	15:00	6334.95	-1646.55	136	CTD, WP2, planktometer
21	11	6	17:23	6322.12	-1633.14	138	CTD, WP2, planktometer
22	11	6	20:45	6317.14	-1714.17	161	CTD, planktometer
23	11	6	23:40	6312.72	-1757.27	212	CTD, WP2, planktometer
24	12	6	03:09	6313.85	-1841.61	426	CTD, planktometer
25	12	6	06:00	6313.45	-1921.69	900	CTD, WP2, planktometer
26	12	6	07:25	6317.41	-1926.48	850	CTD, planktometer
27	12	6	08:45	6322.00	-1927.44	107	CTD, WP2, planktometer, ring net
28	12	6	10:24	6313.35	-1922.74	461	CTD, planktometer
29	12	6	10:52	6313.37	-1922.54	500	CTD, ring net (60 min)
30	12	6	15:10	6307.00	-2013.68		CTD, WP2, planktometer
31	12	6	18:30	6302.56	-2057.27	650	CTD, planktometer, ring net (60 min)
32	13	6	00:20	6323.00	-2153.55	164	CTD, WP2, planktometer
33	13	6	03:40	6323.18	-2237.8	255	CTD, planktometer
34	13	6	06:41	6342.84	-2236.92	135	CTD, WP2, planktometer
35	13	6	10:14	6348.22	-2323.35	143	CTD, WP2, planktometer, ring net (30 min)
36	13	6	13:54	6404.54	-2306.22	101	CTD, WP2, planktometer

Appendix 4: Table. Mesozooplankton depth distribution at stations with elevated biomass

Mesozooplankton depth distribution at stations with elevated biomass (cf. Figure 1). Numbers for each depth represent plankton volume in ml per 15 minutes towing time of the planktometer.

Depth	Stations									
(m)	5	6	11	12	16	17	25	31	32	36
0	0	0	0	0	2	1	8	7	1	0
5	3	3	0	1	5	1	5	5	2	5
10	2	2	4	5	7	<1	4	3	5	3
15	2	3	4	6	7	1	3	4	6	2
20	6	2	3	4	5	2	4	4	5	<1
30	6	2	1	6	7.5	5	3	2	2	<1
50	3	7	2	6	8	4	3	3	1	<1

HAFRANNSÓKNASTOFNUN

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