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Trophic relationships and the role of *Calanus* in the oceanic ecosystems south and north of Iceland

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Summary
The aim of this study was to increase the knowledge on the role of *Calanus* copepods and trophic relations of the key components of the oceanic ecosystems south-west (Atlantic waters) and north (Arctic and sub-Arctic waters) of Iceland. The trophic relationships and energy transfer to higher trophic levels were estimated by using fatty acid trophic markers and by applying stable isotopes of carbon and nitrogen. The energy rich *Calanus* species are key links between primary producers and higher trophic levels in the Icelandic waters. The *Calanus* species dominate the zooplankton biomass around Iceland and their markers (20:1n9 and 22:1n11) are found in high amount in animals at higher trophic levels. *Calanus finmarchicus* plays important role as a forage species in the Atlantic water south-west of Iceland while its high importance is replaced by the larger lipid rich *C. hyperboreus* in the Arctic and sub-Arctic waters north of Iceland. Even though *Calanus* based food-web is the main driver in both areas, there exist a pathway where *Calanus* species are of less importance and the energy is channeled via euphausiids to higher trophic levels. This study presents novel important knowledge on the food web structures and carbon flow in Icelandic waters.

Introduction
The waters south and north of Iceland vary greatly both oceanographically and biologically with the rather stable and warm Atlantic waters south and west of Iceland and the more variable and cold Arctic and sub-Arctic waters, north and east of Iceland. These areas serve as important feeding grounds for some ecologically and economically important fish species such as redfish (*Sebastes mentella*, south-west of Iceland) and capelin (*Mallotus villosus*, north of Iceland). Zooplankton are an important food component in the diet of most fish species in Icelandic waters at some stages of their life cycle, either being consumed directly as by capelin and herring (*Clupea harengus*) or indirectly as by demersal fish feeding on planktivorous fish, e.g. capelin is important in the diet of cod (*Gadus morhua*) and marine mammals. Key zooplankton species, such as *Calanus* copepods and euphausiids, convert low energy sugars and protein in phytoplankton to high energy lipids and thus transferring energy directly from the primary producers to fish. One of the aims of this study was to expand the traditional stomach content studies with the use of new techniques like stable isotope and fatty acid (FA) analyses that provide complementary information on the diet. Such investigations provide an integration of prey consumed over periods ranging from weeks to months. The trophic position of the species can be deduced from stable isotope values, and FAs and alcohols may give detailed information about their diet.

Materials and Methods
Samples for this trophic study were collected during August 2007 and 2008 north of Iceland and in June 2003 and 2004 southwest of Iceland. The ratios between heavy and light stable isotopes of carbon and nitrogen ($^{13}C/^{12}C$ and $^{15}N/^{14}N$ respectively) were analyzed. Prior to the analyses the lipids were extracted from the samples in order to reduce variability due to isotopically lighter lipids, since lipids are depleted in ^{13}C relative to proteins and carbohydrates. For determining tropic levels (TL) the method described by Fisk *et al*. (2001) was used, with trophic level 2 used as baseline. Southwest of Iceland it was assumed that *Calanus finmarchicus* from summer samples represented trophic level 2

while north of Iceland spring samples of *C. hyperboreus* were used as a representative of trophic level 2. The following relationship was used for each individual sample of other tropic levels:

$$TL_{consumer} = 2 + (\delta^{15}N_{consumer} - \delta^{15}N_{Calanus.})/F$$

where $TL_{consumer}$ is the trophic level of an organism, $\delta^{15}N_{Calanus}$ is analytically determined as 3.5‰ south of Iceland and 5.6‰ north of Iceland, and F is the isotopic enrichment factor (3.8, Hobson and Welch, 1992).

Fatty acid trophic markers (FATMs) are fatty acids that are transferred relatively unchanged through the food chain. FATMs and fatty acid profiles were used follow energy transfer and to study predator-prey relationships.

Results and Discussion

Calanus based food web is an important driver for the pelagic ecosystem in Icelandic waters. High levels of *Calanus* markers (20:1n9 and 22:1n11) in most of the species signifies the importance of *Calanus* copepods as an energy pool for higher trophic levels (Figure 1). *Calanus finmarchicus* is of higher trophic importance in the south than north whereas the opposite is true for *C. hyperboreus.*

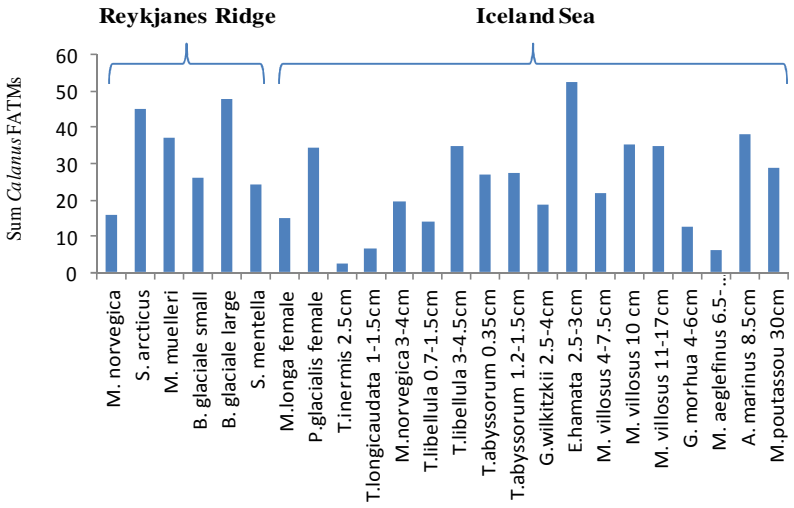

Figure 1. Sum of *Calanus* moieties (relative amounts) of the studied species southwest (over the Reykjanes Ridge) and north (in the Iceland Sea) of Iceland.

Although *Calanus* is the main driver in both areas there exists a trophic pathway were *Calanus* species are of less importance. There the energy is transferred via the euphausiid *Meganyctiphanes norvegica* to the redfish *Sebastes mentella* over the Reykjanes Ridge and through the euphausiids *Thysanoessa inermis* and *T. longicaudata* to higher trophic levels in the Iceland Sea.

About four trophic levels were observed in the two oceanic ecosystems studied. In both regions, the adult pelagic fish occupied the highest trophic level. In early summer, herbivorous copepods occupied the lowest trophic levels. In late summer in the most of the zooplankton species are either omnivorous or strictly carnivorous. Southwest of Iceland vertically migrating mesopelagic fish create a trophic structure that links primary production and the primary grazer *C. finmarchicus* in the upper layer, to predatory mesopelagic fish in the food web in the deep-scattering layers. This vertically migrating behavior contributes to an active energy transport from the upper layers to the deeper ones.

References

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