Changes in forage fish communities in the eastern Canadian Arctic have a limited impact on nutritional quality of the prey base in terms of essential fatty acids, selenium, and selenium:methylmercury ratios

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Introduction

Sea ice loss is leading to the poleward range expansion of sub-Arctic marine prey fish. Capelin (*Mallotus villosus*) and sand lance (*Ammodytes spp.*) are becoming more abundant in low to mid-latitude regions of the eastern Canadian Arctic. The presence of these fish along with declines in availability of the keystone species Arctic cod *(Boreogadus saida*), have led to shifts in the diet of Arctic piscivores (Provencher *et al.* 2012; Yurkowski *et al.* 2016). Yet, the impacts of this change on food web nutrient dynamics are not fully understood.

Quantifying essential fatty acids and selenium can indicate important aspects of the nutritional value of marine fish (Reyes *et al*. 2016). Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are essential fatty acids that play an important role in development, structure of cell membranes, and anti-inflammatory responses (Tocher 2017). Another important nutrient is selenium, which is involved in, e.g. protection against oxidative stress (Mehdi *et al*. 2013). Additionally, selenium has been suggested to offer protection against methylmercury (MeHg) toxicity, as selenoproteins can bind to MeHg, reducing its bioavailability in organisms (Ralston and Raymond 2010).

In a recent study, we measured levels of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs) and total mercury (THg) in important prey fish and invertebrates in the eastern Canadian Arctic, including Arctic cod and the sub-Arctic capelin and sand lance (Pedro *et al.* 2017). Here, we additionally measure levels of essential fatty acids and selenium to provide a more fulsome understanding of the potential effects of climate-induced redistributions of forage species on the health of Arctic marine piscivores.

Objectives

Evaluate and compare nutritional value of sub-Arctic versus Arctic prey fish and invertebrates:

- ❖ Levels of polyunsaturated fatty acids (ΣPUFA), Σ*omega*-3 and essential EPA+DHA, selenium and Se:MeHg ratios
- ❖ Evaluate the influence of ecological (relative carbon source and trophic position, indicated by carbon and nitrogen stable isotopes, resp.) and biological (fish length and lipid content) variables on nutrient variation among species

Methods

- ❖ Samples collected by local fishers, and in conjunction with complementary projects, in the low (Arviat), mid- (Clyde River) and high (Resolute Bay) eastern Canadian Arctic, from 2012-2014 (Table 1, Figure 1)
- ❖ Fatty acid, MeHg, and selenium levels measured in fish muscle and whole invertebrates, and compared among species using linear models (one-way ANOVA) followed by post-hoc Tukey's honestly significant difference tests (excluding amphipods)
- ❖ Influence of biological/ecological variables evaluated (excluding amphipods and northern shrimp) using mixed effects models (R version 3.4.2; significance at $p < 0.05$)

Table 1. Sampling collection details for prey fish and invertebrates in the eastern Canadian Arctic.

	n	Location
Arctic cod	20	Clyde River
(*Boreogadus saida*)	20	Resolute Bay
Capelin		
(*Mallotus villosus*)	11	Arviat
Sand lance		
(*Ammodytes spp.*)	13	Arviat
Sculpin		
Myoxocephalus spp.	10	Arviat
Cottunculus microps	10	Clyde River
Myoxocephalus spp.	10	Resolute Bay
Northern shrimp		
(*Pandalus borealis*)	10	Clyde River
Amphipods		
Gammarus oceanicus	1 pool	Arviat
Themisto libellula	1 pool	Clyde River
Gammarus setosus	2 pools	Resolute Bay
Greenland cod		
(*Gadus ogac*)	10	Arviat
Cisco		
(*Coregonus artedi*)	5	Arviat

Figure 1. Sampling locations of prey fish and invertebrates collected from 2012-2014 in the eastern Canadian Arctic Territory of Nunavut.

Results and discussion

1. Essential fatty acids

- ❖ Higher ΣPUFA, Σ*omega*-3 and EPA+DHA levels in **Arctic cod**, **capelin**, **sand lance** and **cisco**, and quantitatively lower levels in **sculpins**, **Greenland cod** and **northern shrimp** (Figure 2a; similar results for ΣPUFA and Σ*omega*-3)
- ❖ No differences in fatty acid content among **capelin**, **sand lance** and **Arctic cod**
- ❖ No regional variation for **Arctic cod**; higher fatty acid content in **sculpins** in high Arctic (HA) compared to mid-Arctic (MA) - likely related to differences in diet and lipid content among sculpin species (Giraldo *et al.* 2016)
- ❖ Levels of ΣPUFA, Σ*omega*-3 and EPA+DHA significantly explained by lipid content and its interaction with trophic position (Figure 2b) - fatty acid levels in **Greenland cod**, **sculpin** in low Arctic (LA) and MA, **capelin** and **sand lance** (trophic levels > 3.5) more strongly predicted by lipid content compared to **Arctic cod**, **cisco** and **sculpin** in HA (trophic levels < 3.5), suggesting differences in retention and/or de novo synthesis capacity at lower trophic levels (Kainz *et al.* 2017)

2. Selenium and Se:MeHg ratios

- ❖ Higher levels of selenium in **sand lance** ($p < 0.05$) compared to all other species (Figure 3a)
- ❖ Higher Se:MeHg molar ratios in **capelin** and **sand lance**, followed by **Arctic cod** ($p < 0.05$; Figure 3b)
- ❖ Ratios of Se:MeHg >1 for all species, suggesting protection against MeHg toxicity (Ralston and Raymond 2010)
- ❖ Selenium only weakly related to relative carbon source and no other factors (likely driven by high levels in some sand lance), suggesting homeostatic regulation of selenium in organisms (Ralston and Raymond 2010)
- ❖ Se:MeHg ratios related to fish length (Figure 3c) and relative carbon source (Figure 3d), likely due to effects of these factors on MeHg variation

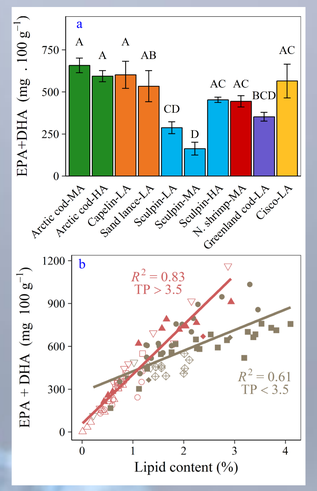

Figure 2. a) Levels of essential EPA+DHA (mg. 100 g^{-1} wet weight (ww)) and b) relationship of EPA+DHA with lipid content (%) and trophic position (TP) in forage fish and invertebrates in the low (LA), mid (MA) and high (HA) eastern Canadian regions of Nunavut from 2012-2014.

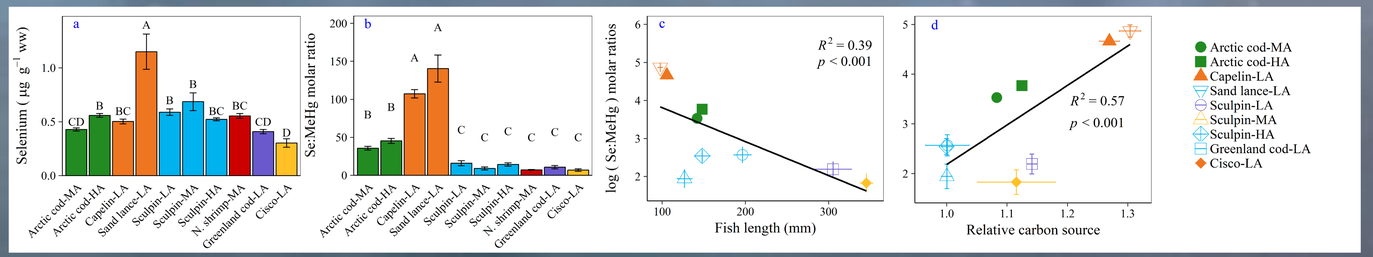

Figure 3. Levels of a) selenium (µg g^{-1} ww) and b) Se:MeHg molar ratios and relationship of c) Se:MeHg ratios to fish length and d) Se:MeHg ratios to relative carbon source in muscle tissue of forage fish and invertebrates in the low (LA), mid-(MA) and high (HA) eastern Canadian Arctic from 2012-2014.

Conclusions

- ❖ Similar or higher levels of important fatty acids and selenium in sand lance and capelin compared to Arctic cod, and higher Se:MeHg ratios in sub-Arctic fish compared to Arctic cod
- ❖ We previously found highest levels of PCB and OCs in sculpin and northern shrimp; comparing sub-Arctic fish to Arctic cod, we found higher PCB and most OCs in capelin and sand lance, by only two-fold or less, and higher THg and MeHg in Arctic cod compared to sub-Arctic fish (Pedro *et al*, 2017)
- ❖ **Taken together, these results indicate that the replacement of Arctic cod with capelin and sand lance is unlikely to have adverse effects on the prey quality of the forage base for Arctic piscivores, at least with respect to prey content of legacy organic contaminants, MeHg, key fatty acid and selenium**

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Questions or comments?
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