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

Sara Pedro1, Aaron Fisk2, Steven Ferguson3, Nigel Hussey2, Steven Kessel1, Melissa McKinney1

1University of Connecticut, CT, USA; 2University of Windsor, ON, Canada; 3 Fisheries and Oceans Canada, Canada; 4John G. Shedd Aquarium, Chicago, IL, USA

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; Yarkowski 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 (Mehlil et al. 2013). Additionally, selenium has been suggested to offer protection against methylmercury (MeHg) toxicity, as selenium 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, sub-Arctic fish and the sub-Arctic 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 (EPUFA), Σomega-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 amphiboids);
- Influence of biological/ecological variables evaluated (excluding amphiboids and northern shrimp) using mixed effects models (R version 3.4.2; significance at p < 0.05).

Results and discussion

1. Essential fatty acids

- Higher ΣPUFA, Σomega-3 and EPA+DHA levels in Arctic cod, capelin, sand lance and eelen, and quantitatively lower levels in scallops, Greenland cod and northern shrimp (Figure 2a; similar results for ΣPUFA and Σomega-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 scallops in high Arctic (HA) compared to mid-Arctic (MA) – likely related to differences in diet and lipid content among scallop species (Giraldo et al. 2016);
- Levels of ΣPUFA, Σomega-3 and EPA+DHA significantly explained by lipid content and its interaction with trophic position (Figure 2b); fatty acid levels in Greenland cod, scallop in low Arctic (LA) and MA, capelin and sand lance (trophic levels > 3.5) more strongly predicted by lipid content compared to Arctic cod, eelen and scallop in HA (trophic levels < 3.5), suggesting differences in retention and/or de novo synthesis capacity at lower trophic levels (Kaintz 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.

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 scallop 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 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.

Questions or comments?

sara.pedro@uconn.edu

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

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>No.</th>
<th>Depth (m)</th>
<th>Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctic cod</td>
<td>Resolute Bay</td>
<td>20</td>
<td>100-150</td>
<td>20-30</td>
</tr>
<tr>
<td>Capelin</td>
<td>Clyde River</td>
<td>15</td>
<td>10-100</td>
<td>15-30</td>
</tr>
<tr>
<td>Sand lance</td>
<td>Clyde River</td>
<td>10</td>
<td>10-100</td>
<td>15-30</td>
</tr>
<tr>
<td>Salmon</td>
<td>Resolute Bay</td>
<td>10</td>
<td>10-100</td>
<td>15-30</td>
</tr>
</tbody>
</table>

Figure 1. Levels of essential EPA+DHA, Σomega-3 and essential EPA+DHA, selenium and Se:MeHg ratios.