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Short communication

The role of salmonids in the diet of grey and ringed seals in the Bothnian Bay, northern Baltic Sea

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ABSTRACT

We examined the digestive tract contents of 63 Baltic grey seals (*Halichoerus grypus*) and 37 Baltic ringed seals (*Phoca hispida botnica*) collected during May to November in 2008 and 2009 in the northern part of the Bothnian Bay to assess the role of Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) in the diet of seals. For grey seals the three most common prey species in numbers were vendace (*Coregonus albula*), Baltic herring (*Clupea harengus*) and common whitefish (*Coregonus lavaretus*). Thirteen grey seals contained remnants of a total of 93 salmonids (Atlantic salmon and sea trout). Salmon ingested were, in general, older and larger than the ingested sea trout. Six grey seals had in their digestive tract Carlin-tags which are used to mark stocked salmonid smolts. Stocked sea trout appear particularly vulnerable to predation during the first months after the stocking. Our study suggests that salmonids may play a marked role in the diet of grey seals during the season when salmonids aggregate in coastal waters in the Bothnian Bay. Three-spined stickleback (*Gasterosteus aculeatus*), Baltic herring, smelt (*Osmerus eperlanus*) and vendace dominated in the ringed seal's diet. No salmonids were found in the dietary tracts of ringed seals.

1. Introduction

There is an intense dispute over the impact of seal populations on Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) populations in the Atlantic Ocean and Baltic Sea (Carter et al., 2001; Middlemas et al., 2003, 2006; Jounela et al., 2006; Matejusova et al., 2008). These two fish species have a special iconic status and the health of many populations is a current concern (ICES, 2011a,b). The possibility that seals may adversely affect salmonid populations by predation has led to demands for control of seal populations (Carter et al., 2001; Yodzis, 2001; Stenman, 2007; Graham et al., 2011). It is a complicated and controversial issue (Varjopuro, 2011), and any discussion of this issue has been constrained by a lack of data.

The grey seal (*Halichoerus grypus*) is the largest and most abundant of the two seal species inhabiting the northern Baltic Sea. The Baltic grey seal population started to recover in the late 1980s and since then the annual rate of increase of the grey seal population has been about 7.5% (Harding et al., 2007). In 2010, the Baltic grey seal population recorded by aerial censuses was 23100 (Kunnasranta, 2010). Most of these seals were counted in the Gulf of Bothnia and in the northern Baltic proper.

Baltic grey seal feed on more than twenty different fish species although only a few species contribute substantially to the diet (Söderberg, 1975; Lundström et al., 2010). Baltic herring (*Clupea harengus*) dominates the diet in both numbers and biomass, and in all ages (Stenman and Pöyhönen, 2005; Lundström et al., 2007, 2010). Common whitefish (*Coregonus lavaretus*) is important in the Gulf of Bothnia and sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) in the central Baltic (Lundström et al., 2010). Atlantic salmon and sea trout have been found typically in less than 5% of the Baltic grey seals examined, and mainly in older grey seals collected from the Gulf of Bothnia (Stenman and Pöyhönen, 2005; Lundström et al., 2010). It is noteworthy, however, that most of the samples in these studies have been collected at times and in areas where seals and salmonids are not generally found to co-exist to any large extent.

The main concentration of the Baltic ringed seal (*Phoca hispida botnica*) population resides in the Bothnian Bay, in the northernmost part of the Baltic Sea (Helle, 1980). Since 1988, the ringed seal population in the Bothnian Bay has grown approximately 4.5% yearly and in the most recent aerial censuses about 6500 seals were counted (Kunnasranta, 2010; WWF, 2011). Typical prey fish for the Baltic ringed seal are the three-spined stickleback (*Gasterosteus aculeatus*), Baltic herring and other small-sized fish and crustaceans (Stenman and Pöyhönen, 2005; Sinisalo et al., 2008).

Efforts to assess seal-salmonid interactions in the Baltic Sea have been restricted because only a few seal diet samples have been collected in the Bothnian Bay during salmon spawning migration which begins in late May and peaks in late June. The number

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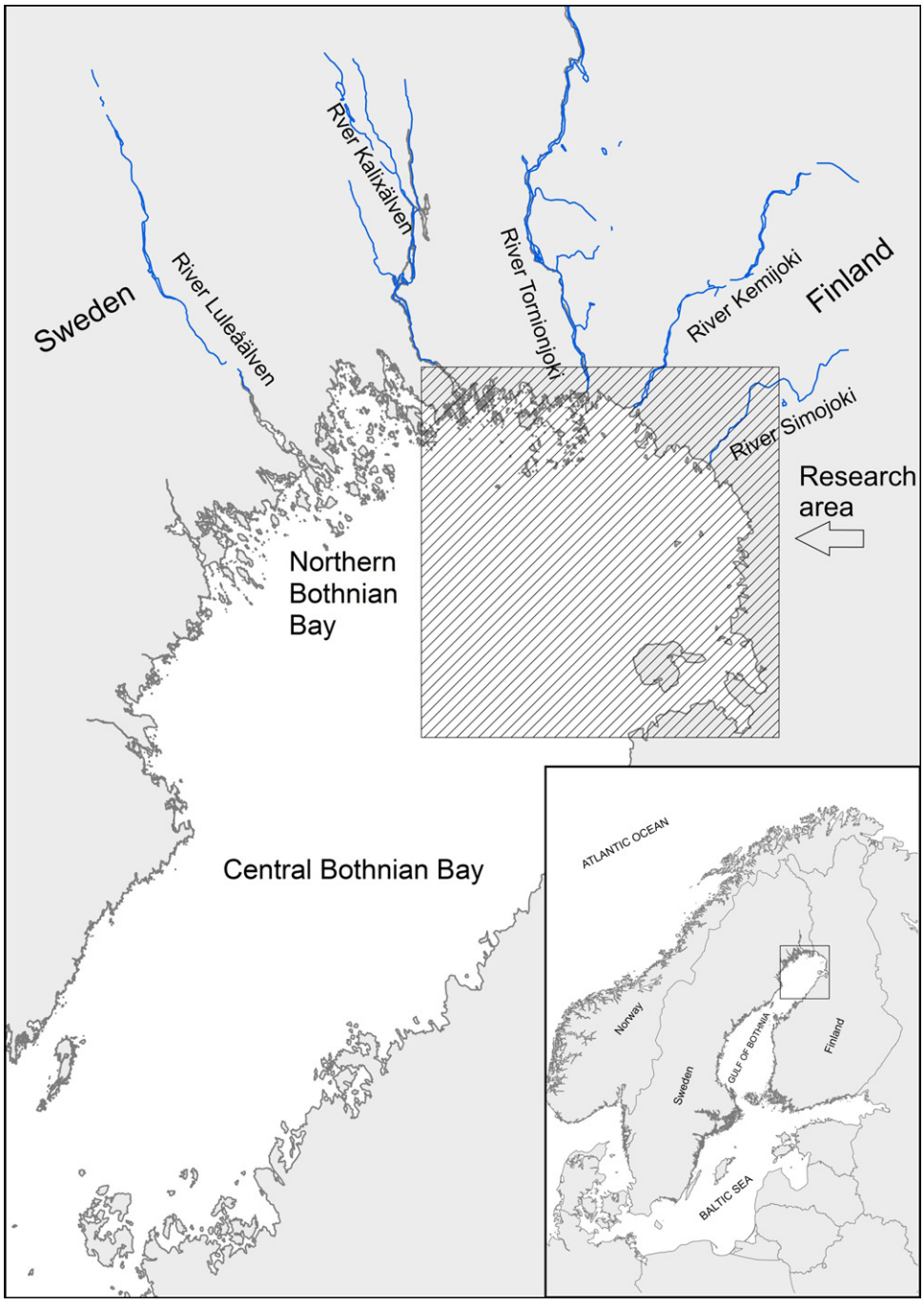

Fig. 1. The research area in the northern Bothnian Bay.

of salmon migrating from the Baltic proper towards their home rivers or stocking areas in the Bothnian Bay in 2002–2008 varied between 80 000 and 200 000 (Siira et al., 2006; Suuronen and Jounela, 2010). Furthermore, in early summer more than 2 million wild salmon smolts (length 12–17 cm) migrate to the sea from the rivers descending to the Bothnian Bay (ICES, 2011a) and about 2 million salmon smolts and 0.6 million sea trout smolts are annually stocked in the river mouths (ICES, 2011a).

To have a better understanding of the role of salmon and sea trout in the diet of grey and ringed seals during the period of high vulnerability for salmonids, we conducted a diet study in 2008 and 2009 to obtain more accurate information about the diet composition of seals in the Bothnian Bay.

2. Materials and methods

Altogether 63 grey seals and 37 ringed seals (Table 1) were collected in 2008 and 2009 during the open water (ice-free) period between mid May and late November in the northern part of the Bothnian Bay (Fig. 1). In 2008, the majority of seals were collected during June–July whereas in 2009 the collection extended over a wider period. Seals were collected by shooting them in the shallow water near hauling-out sites under special research permissions. There was no selection of animals shot. Sex and weight were determined for all seals. Age of seals was determined using the longitudinal sections of the canine teeth.

Digestive tracts (stomach and intestines) of seals were placed in plastic bags and stored in dry ice for later examination. In the

Table 1
Number of grey and ringed seals collected monthly in 2008 and 2009.

	May	June	July	August	September	October	November	Total
Grey seal 2008	2	9	8	0	0	0	0	19
Grey seal 2009	3	6	12	0	11	4	8	44
Ringed seal 2008	3	9	0	0	0	0	0	12
Ringed seal 2009	8	1	1	0	0	11	4	25

laboratory, whole prey items were removed, identified and measured separately. Hard parts from the remaining contents were separated after repeated washing and straining of stomach and gut content using a series of sieves with decreasing mesh size according to process described by Stenman and Pöyhönen (2005).

Determination of prey species was mainly based on the identification of fish otoliths which are the hardest parts of the bony fishes and most resistant against digestion and mechanical wearing. Otoliths are species-specific and usually recognizable in the alimentary tract. However, salmonid otoliths are small and easily eroded (Boyle et al., 1990). In several cases it was not possible to identify with full certainty whether a salmonid was Atlantic salmon or sea trout. Likewise, it was often difficult to determine whether a fish was a vendace (*Coregonus albula*) or a common whitefish. Other hard particles such as skull parts, vertebrae, gill bones and spines were used to help in the determination of prey species. A reference material of otoliths and skeletons collected in the study area was used to identify the prey items. The number of individuals per each prey species eaten by a seal was the sum of the number of whole prey items and the count of otoliths divided by two.

The age of salmonids was estimated using the ingested otoliths and Carlin-tags. Carlin tags are used to mark stocked fish and approximately 1.5% of all stocked salmon and trout are yearly tagged in the Bothnian Bay (Salminen et al., 1995). The information in the tag allows the species and the exact time and place of the stocking to be determined. The age determination from the otoliths was often difficult because of otolith erosion.

3. Results

3.1. Seal size and age composition

The average weight of grey seals shot was 82.4 kg (range 25–201 kg) and the average age 7.3 years (range 0–29 years). 55% were classified as mature adult grey seal (i.e., 5 years or older), and 19 were male and 44 female. The average weight of ringed seals shot was 55 kg (range 18–103 kg) and the average age 8.6 years (range 0–27 years). 70% of the ringed seals were classified as mature (i.e., 5 years or older), and 20 were male and 17 female.

3.2. Diet of grey seal

The wet weight of digestive tract content among the grey seals varied between 4 and 4714 g (average 338 g). The three most common species in numbers in the diet were vendace, Baltic herring and common whitefish (2008 and 2009 data pooled). Vendace were found in digestive tracts of 17 grey seals and the average number was 40 (range 1–152). Common whitefish occurred in digestive tracts of 15 seals (average 9.2, range 1–36). Furthermore, there were unidentified *Coregonus* family fish (vendace/common whitefish) in 19 digestive tracts (largely in the same digestive tracts where vendace and common whitefish were found). Baltic herring were found in 25 digestive tracts (average 13.2, range 1–80).

Altogether, 684 vendace, 139 common whitefish, 147 *Coregonus* spp., 330 Baltic herring, 93 salmonids, 67 cyprinids, 32 smelt (*Osmerus eperlanus*), 15 perch (*Perca fluviatilis*), 4 burbot (*Lota lota*), 2 river lamprey (*Lampetra fluviatilis*), 2 three-spined stickleback and 182 unidentified fish were recorded in the digestive tract of 63 grey seals (Fig. 2). All 67 cyprinids were found in one female grey seal (weight 136 kg, age 24 years).

3.3. Salmon and sea trout in the diet of grey seal

The digestive tract of 13 grey seals (20% of all) contained remnants of 93 salmonids (Table 2). Four grey seals had remnants of sea trout in their digestive tracts. Most of these were smolts and originated from one seal. A total of 12 salmonids could be identified with high certainty as Atlantic salmon and they were found in five grey seals. Seven of these salmon were found in one male grey seal (weight 137 kg). In most cases the length of these salmon could not be determined accurately because of decomposition but otolith analysis suggested that most of these salmon had been one (1SW) or two years at sea (2SW). Hence, they were adult salmon and their length would have been more than 50 cm. The length of one large salmon could be estimated more accurately and it was approximately 1 m in length. This fish had no head and it was found in the stomach of a large male grey seal (188 kg) shot on 12 June 2008. Nine salmonids could not be identified by species.

Six grey seals had Carlin-tags in their digestive tract (Table 2). Most (7 out of 9) of these tags had been used to tag sea trout smolt. These tags suggest that seal predation on stocked salmonids takes place mainly in the year of stocking but also during the next year. Four out of seven tags were from trout that were stocked within two months of the tag discovery. All tagged fish had been stocked in the river mouths or rivers descending into the Bothnian Bay (both in the Finnish and Swedish side of the bay). One grey seal had four tags (Fig. 3). Three of these tags originated from the sea trouts stocked two weeks earlier in the mouth of the River Kemijoki and one from a trout stocked in 2007 in the mouth of the River Iijoki. This very same seal had remnants of about 60 young sea trout which on the basis of otoliths and bones were mainly smolts of about 20 cm in length and likely stocked fish. This particular grey seal was shot 26 May 2008 near the border of Finland and Sweden.

The average weight of those 13 grey seals (114 kg) that had salmonids in their digestive tract was significantly higher (Mann–Whitney *U*-test, df = 1, $p = 0.003$) than the weight of other grey seals (73 kg). Nine of these seal were female and four were males (Table 2). It is noteworthy that the four largest of these 13

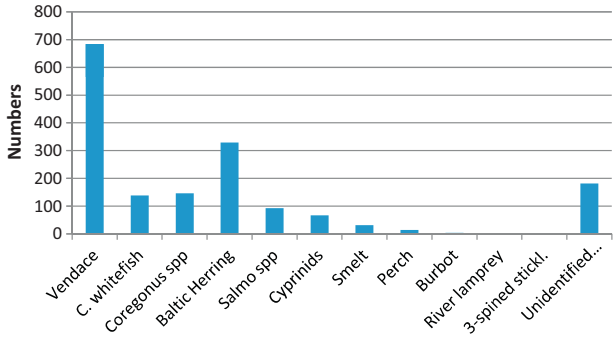

Fig. 2. Total number of various fish species recorded in the digestive tract of 63 grey seals sampled in this study.

Table 2
Date of capture, weight and sex of grey seals that had ingested salmonids, the number of salmonids and Carlin tags observed in the digestive tract and the time and place of stocking. Information on age of salmonids inferred from otolith analysis is indicated in footnotes. SW indicates the number of years at sea (sea winters).

Date of capture	Weight of seal (kg)	Sex of seal	Salmon	Sea trout	Salmon/sea trout (unid.)	Carlin tags species	Time and place of stocking
26 May 2008	110	F		>60[a]		4 tags, sea trouts	3 trouts, May 2008 in R. Kemijoki; 1 trout, May 2007 in R. Iijoki
30 May 2008	118	F			1		
05 June 2008	42	F			2		
12 June 2008	188	M	1[b]				
08 July 2008	137	M	7[c]		1		
10 July 2008	72	F	1			1 tag, salmon	2007 in River Luleälv
09 July 2009	110	F	2[d]				
22 July 2009	143	M	1[e]			1 tag salmon	May 2008 in R. Kemijoki
22 July 2009	43	F		1		1 tag, sea trout	May 2008 in R. Skellefteälv
30 July 2009	136	F		1		1 tag, sea trout	May 2009 in R. Iijoki
23 October 2009	95	F		1	3[f]	1 tag, sea trout	May 2009 in R. Tornionjoki
19 November 2009	165	M			1		
19 November 2009	127	F			1		
Total number			12	>63	9	9	

[a] Sea trout smolts, about 20 cm in length.
[b] Salmon, ca 1 m in length (on the basis of scale reading, this salmon was 3SW or older).
[c] Four salmon 1SW or older; two salmon 2SW or older (one otolith too eroded to assess the age).
[d] Two salmon, 2SW or older.
[e] Salmon, 1SW or older.
[f] Two salmonids, 2SW or older (otoliths too eroded to assess the age).

grey seals were all males and at least three of them had ingested adult Atlantic salmon. All of the four grey seals with sea trout in their digestive tracts were females (average weight 96 kg). The occurrence of salmonids in the digestive tracts was higher in 2008 (32% of seals) than in 2009 (16%). Salmonids were found in the digestive tract of grey seals over the whole sampling period although salmon were found only in the samples taken in June–July.

3.4. Diet of ringed seal

The wet weight of digestive tract content in ringed seals varied between 0 and 219 g and the average was 21.5 g. Of the 37 ringed seals collected in this study 20 (54%) had eaten three-spined stickleback and the average number was 83 (range 1–402). 18 ringed seals had remnants of Baltic herring in their stomach (average 9.8 herring, range 1–55). In total, 1652 three-spined sticklebacks, 177 Baltic herring, 39 smelt and 37 vendace were recorded in the ringed seals. Digestive tracts also included some other fish species such as small sandeel (*Ammodytes tobianus*), sand goby (*Pomatoschistus minutus*) and isopod crustaceans. No evidence of salmonids was found in the digestive tracts of these seals.

Fig. 3. Example of the washed content of the digestive tract of a grey seal shot on 26 May 2008. There are bones and otoliths of sea trout smolts of about 20 cm in length and four Carlin-tags. Photo on the courtesy of Mia Valtonen.

4. Discussion

The occurrence of salmonids in the grey seal's diet in this study was substantially higher than in previous studies conducted in the Gulf of Bothnia (e.g. Stenman and Pöyhönen, 2005; Lundström et al., 2007, 2010). This apparently is connected to the time and location of the study. Sampling took place in the northernmost part of the Gulf of Bothnia, in the Bothnian Bay, largely at the time when adult salmon and sea trout aggregate at coastal waters to return to rivers to spawn and when the smolts are descending to the sea. Obviously, both young and adult salmonids are at that time most vulnerable to predation, and grey seals take advantage of the temporary abundance of energy-rich and nutritious salmonid prey.

Salmon found in the digestive tracts of grey seals were generally older and larger than the sea trouts. In particular the large male grey seals appeared to prefer adult salmon although female grey seal also eat adult salmon. Stocked sea trout smolts appeared particularly vulnerable to seal predation during the first weeks or months after the stocking. Caution is needed here, however, because one grey seal had eaten most of these smolts.

Although salmonids were not among the most common species in the diet of grey seals, in biomass their share apparently was high. The rough estimate of biomass for the 12 salmon ingested (assuming a mean weight of 5 kg) is about 60 kg whereas the biomass for the 684 vendace (mean weight 20 g) and 330 herring (mean weight 35 g) ingested is about 14 kg and 12 kg, respectively. This suggests that the biomass of salmon eaten by the grey seals may have been substantially higher than the biomass of the two most common species together. Hence, we have reasonable grounds to speculate that the role of Atlantic salmon in the diet of grey seals is marked during the season when salmon aggregate in coastal waters in the Bothnian Bay.

With regard to sea trout, most fish found in the stomachs were either smolts stocked in the same year (ca. 60 ind.) or young fish stocked year before (2–4 ind.). If we assume that average weight of trout smolts was 0.1 kg and that of older sea trout about 1 kg, the total biomass of sea trout ingested was about 8–10 kg. This suggests that sea trout may be relatively important food for the grey seals.

Nonetheless, more data would be needed to assess the quantity of salmonids consumed by grey seals and to evaluate the impacts of this predation on salmonid stocks in the Bothnian Bay. It is worth noting that even when aggregated in coastal waters, salmonids are less abundant than the common species such as Baltic herring. Therefore, we cannot expect that salmonids would represent a major component of the general diet of grey seals. However, with the observed level of predation seals might impair salmonid stocks many of which are severely depleted (ICES, 2011a). Middlemas et al. (2003) noted that in areas where salmonid abundance is low, seals could have substantial local effects on populations.

Given the data gaps and uncertainties associated with the methodology, it is not possible to specify to which extent the individual grey seal may be specializing on certain type of prey. Nevertheless, our results suggest that some level of specialization may exist (see also Wright et al., 2007; O'Boyle and Sinclair, 2012). In general, however, empirical data on prey selection by seals is inadequate and the literature on specialization is inconclusive (e.g., Graham et al., 2011).

One could argue that adult salmon found in the digestive tract of grey seal may have been predated in salmon trap-nets that are operated along the Finnish and Swedish coast during the spawning migration of salmon. It is well known that grey seals are able to capture a salmon from a trap-net (Kauppinen et al., 2005; Königson, 2011) and that male grey seal visit these trap-nets more regularly than females (Lehtonen and Suuronen, 2010). We cannot assess whether some of the salmon in our study were predated in a trap-net or in some other gear. Nonetheless, the large salmon (ca. 1 m in length) found in the stomach of a large male grey seal was not predated in a trap-net because the trap-net season had not yet started in that region.

It is worth noting that the role of larger salmonids in the diet of seal can be underestimated in the studies that are based on identification of otoliths and larger bones because grey seal are able to discard the head of larger fish before consumption (Lundström et al., 2007). This is supported by our observation where the large salmon found in the stomach of a grey seal had no head. In a salmon trap-net, a grey seal often eats only the soft parts of salmon (Suuronen et al., 2006). Furthermore, the otoliths of salmonids are relatively small, especially in small individuals, and when eroded, are hard to identify. The use of DNA analysis would be useful to identify prey from which no hard-parts are consumed or the otoliths are quickly eroded.

Our results show that vendace, common whitefish and Baltic herring are important species in the diet of grey seals during the season when salmonids aggregate in coastal waters in the Bothnian Bay. It is noteworthy that earlier diet studies have not recorded vendace as an important prey species for grey seals. The high occurrence of vendace in our study is likely partly because of the location of the study in the core distribution area of the vendace in the Bothnian Bay. Earlier studies may also have misinterpreted possible vendace otoliths as being from common whitefish; they are very similar.

Our study suggests that salmon and sea trout do not play a role in the diet of Baltic ringed seal. The data on ringed seal, however, is small and hence caution is needed in the interpretation of this result.

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