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Reprint of 'Association of helminth infections and food consumption in common eiders *Somateria mollissima* in Iceland'

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ABSTRACT

Common eider *Somateria mollissima* L. 1758, subsp. *borealis*, is widely distributed along the coasts of Iceland. In this study association of parasite infections and food composition was studied among 40 females and 38 males (66 adults, 12 subadults), shot under license on four occasions within the same year (February; before egg-laying in May; after the breeding period in late June; and in November) in Skerjafjörður, SW Iceland. Parasitological examinations revealed 31 helminth species (11 digeneans, ten cestodes, seven nematodes, and three acanthocephalans). Distinct digenean species parasitized the gallbladder, kidney and bursa of Fabricius, whereas other helminths parasitized the gastrointestinal tract. Thirty-six invertebrate prey species were identified as food; waste and bread fed by humans, were also consumed by some birds. *Amidostomum acutum* was the only parasite found with a direct life cycle, whereas other species were food transmitted and ingested with different invertebrate prey. Opposite to females male birds rarely utilized periwinkles and gammarids as a food source. As a result, *Microphallus* and *Microsomacanthus* infection intensities were low except in February, when subadult males were responsible for an infection peak. Females caring for young increased their consumption of periwinkles close to the littoral zone in June; during pre-breeding, females also increased their gammarid intake. As a consequence, *Microphallus* and *Microsomacanthus* infection intensities temporarily peaked. Increased food intake (including *Mytilus edulis*) of females before the egg-laying period resulted in twofold higher *Gymnophallus bursicola* infection intensity than observed for males. *Profilicollis botulus* infection reflected seasonal changes in decapod consumption in both genders. Different life history strategies of males and females, especially before and during the breeding season and caring of young, and during molting in distinct feeding areas in summer, promote differences in consumption of prey-transmitted parasites that result in distinct infection patterns of the genders.

1. Introduction

The common eider *Somateria mollissima* L. 1758, subsp. *borealis*, is a sea duck that is widely distributed along the coasts of Iceland. Recently, 850 000 eiders were estimated to overwinter around the island (Garðarsson, 2009); other estimates have suggested an autumn population of almost 1 million birds and more than 200 000 breeding pairs (Petersen and Skirnisson, 2001; Skarphéðinsson, 1996). Nesting eiders are economically important because of their down and, thus, are usually protected and managed in breeding colonies, where the valuable down (annually approximately 3 tons) is harvested from the nests.

After a massive spring bloom of plankton in 1991 north of Iceland, oil and other substances from decomposing zooplankton drifted ashore in Strandir, NW Iceland. Thousands of eiders (mainly ducklings) became covered in oil and subsequently perished in this natural catastrophe. Dissection and parasitological examination of beached adults confirmed their poor condition and extensive intestinal helminth infections (Skirnisson and Snæbjörnsson, 2001). However, until this point, few intestinal helminths had been reported to infect common eiders in Iceland; two trematodes (Brinkman, 1956), four cestodes (Baer, 1962), and two acanthocephalans (Wesenberg-Lund, 1952). Nematodes had not been reported. Comparing this relatively short list with those 83 eider helminths already enlisted by McDonald (1969) suggested that several species were still unknown to parasitize eiders in Iceland. To improve knowledge on parasite infections of this economically important species, and to examine the general health status of the population, systematic studies on the eider duck population in Skerjafjörður, SW Iceland began in 1993. To assess seasonal and sex-related variations, the same number of female and male birds was examined at four sampling dates throughout the year: in February, May, June, and November. Special emphasis was placed on studies of helminth infections. Given that most eider parasites are food transmitted, prey selection and diet composition were also studied (Skirnisson et al., 2000). Furthermore, seasonal variation in body mass, size of ovarian follicles and testis, and participation of females in reproduction were studied and the morphometry examined (Skirnisson, 2001; Skirnisson et al., 2003b).

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The aims of the article were to i) list and describe the helminth fauna of common eiders in Skerjafjörður, and compare the findings to studies previously performed on eiders in Europe and Canada; ii) examine prey selection and dietary composition of both genders in the area; iii) examine some typical helminth-prey associations in the area by comparing seasonal prey consumptions and parasite infections; iv) report on the sex-related and seasonal infections by a nematode species with a direct life cycle; and v) discuss factors that might explain the helminth infection patterns observed in the survey.

2. Materials and methods

2.1. Study area and bird sampling

The study area was the inner part of Skerjafjörður (64°05′59 N, 21°56′29 W), a shallow fjord (depth 1–4 m) south of the Reykjavík capital area with sea bays, shingle, and stony beaches, peninsulas, intertidal flats, brackish lagoons, and marshes. Various types of substrate (i.e. hard substrate, gravel, sand, and mud) characterize the intertidal zone and the fjord bed; the invertebrate fauna is rich and diverse (Garðarsson and Aðalsteinsdóttir, 1977; Ingólfsson, 1977).

In total, 78 eiders were shot with a shotgun (under license issued by the Ministry of Environment) in the morning hours from a Zodiac rubber boat (powered by outboard motor) on four sampling dates in 1993; 10 February, to evaluate the mid-winter status; 11 May (before the incubation period); 24 June (post-breeding period, females with newly hatched young sampled close to the littoral zone in the vicinity of a breeding colony with approximately 3000 nests), and 2 November (late autumn/early winter status). Ten females and ten males were sampled each time except in November, when ten females and eight males were sampled.

2.2. Dissection, measurements, and sampling

Birds were autopsied fresh at the Institute for Experimental Pathology, Keldur, on the day of sampling. Body mass was obtained with a 5-g accuracy and three external morphometric measurements (wing, bill, and tarsus) were taken. During the autopsy, the diameter of the largest ova and the length of testis were measured to the nearest mm. Age was confirmed by inspection of the bursa of Fabricius (present in subadult birds, but absent in adults). The alimentary tract was removed and divided into the proventriculus, gizzard, small intestine, ceca, and rectum with cloaca and bursa of Fabricius (if present). Each part was kept frozen at −18 °C in separate plastic bags until analyzed during the following months. The liver and kidneys were also isolated and frozen in plastic bags.

2.3. Examination of food

Before prey identification, a reference collection was established comprising different-sized, undamaged specimens of molluscs (bivalves and gastropods), crustaceans, echinodermatids, and ascidians reported to occur in the study area (Garðarsson and Aðalsteinsdóttir, 1977; Ingólfsson, 1977). Food remains in gizzard were identified under a stereoscope by comparing them with undamaged specimens. The results were recorded in two ways. First, the frequency of occurrence was used to report how often a given prey species was identified in the study. Second, to enable semiquantitative, sex-related, and seasonal comparisons, the volume percentage of each prey group for each gizzard was estimated macroscopically (Skirnisson et al., 2000). The method is quickly performed and each bird had equal input to the results. The disadvantages of this method is that it probably underestimates the volume of soft-bodied prey items, such as polychaetes and fish eggs, which disappear more rapidly from the gizzard compared with, for example, remains of molluscs and crustaceans. Also, the values obtained were not independent of each other, which limit the statistical analysis of the results (Skirnisson et al., 2000).

2.4. Collection and quantification of parasites

After thawing at 4 °C overnight, the small intestines, caeca, rectum with cloaca and bursa of Fabricius (if present) were opened separately with a longitudinal incision and the contents washed into a 100-μm mesh. After gently washing with water, the contents were transferred to a Petri dish and examined under a stereoscope for worms. Parasites were isolated, counted, and fixed in 70% ethanol. Intensity of *Microphallus* spp. and *Microsomacanthus* spp. was estimated from three aliquots in cases when hundreds or thousands of worms were present.

The wall of the proventriculus was examined under a stereoscope for the presence of nodules that form around *Echinuria* nematodes that burrow their anterior end into the mucosa. Nematodes in the lumen of the proventriculus and gizzard were also isolated under a stereoscope. The gizzard membrane was removed with pinsetters under a stereoscope, and *Amidostomum* nematodes were isolated and counted. The gall bladder was separated from the liver and cut open in a Petri dish; then, *Gymnophallus* worms were washed out with tap water, isolated, and counted. Several kidney smears were examined for the presence of *Renicola* eggs under a microscope using 120× magnification. When detected, the renal tissue was torn to small pieces with pinsetters in a Petri dish, and blood and tissue fluids were removed by gently washing the sample under tap water into a 100-μm mesh sieve; any flukes were then isolated and counted. Fixation of parasites followed in 70% ethanol.

2.5. Parasite identification

Trematodes were identified after McDonald (1981), Gibson et al. (2002), Jones et al. (2005), and Bray et al. (2008). Cestodes were identified according to Schiller (1955), Ryzhikov and Rysavý (1985), Schmidt (1986), Regel (2001), and Galkin et al. (2006; 2008). Identification of nematodes was based on McDonald (1974), Wehr (1971), and Anderson (1992), and of acanthocephalans on McDonald (1988).

2.6. Statistical analysis

Descriptive statistics, prevalence of infection, mean intensity of infection, and discrepancy index were calculated for each parasite species using QPweb 3.0 (Reiczigel and Rózsa, 2005). The prevalence of infection is the percentage of hosts infected with the parasite, whereas mean intensity of infection is the mean number of parasites per host in infected individuals only. To calculate the 95% confidence limits, the Sterne method was used for prevalence, and the bootstrap method for mean intensity (Rózsa et al., 2000). The index of discrepancy was calculated to study the dispersal of parasites within the host population (Poulin, 1993). The discrepancy index ranges between 0 and 1, with high values indicating an aggregated distribution and low values a uniform distribution.

A generalized linear model using a binomial distribution and a logit link function was used to compare prevalence of infection among host sex groups and sampling days combined for both sexes. To compare mean infection intensity among host sex groups and sampling days, a generalized linear model using a negative binomial distribution and a log link function was used.

Statistical comparisons were done in Statistica (StatSoft, Inc., 2013). The alpha level, two-tailed, was set at $p = 0.05$ for all tests.

3. Results

3.1. Breeding participation and host age

On 11 May, undeveloped ovarian follicles of four out of ten birds indicated that the females were not participating in breeding in the spring. On 24 June, the presence of brood patches and empty follicles